W P Wood

Transactions of American Society for Steel Treating

Vol. XI January, 1927 No. 1

FEATURES

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TRANSACTIONS
American Society for Steel Treating

VOL. XI — JANUARY, 1927 — NO. 1

NEW OFFICERS ELECTED

THE letter-ballot cast by the members of the American Society for Steel Treating was counted by the tellers of election on December 21. The report of the tellers of election is as follows:

December 21, 1926.

To the Secretary,
American Society for Steel Treating,
4600 Prospect Ave.,
Cleveland, Ohio.

The Committee of Tellers submits the results of the balloting by the membership for National Officers of the American Society for Steel Treating.

Pursuant to the Constitution of the Society, the Committee of Tellers met at the headquarters of the A. S. S. T. at 4600 Prospect Avenue, Cleveland, on this day and counted the letter ballot cast for National Officers.

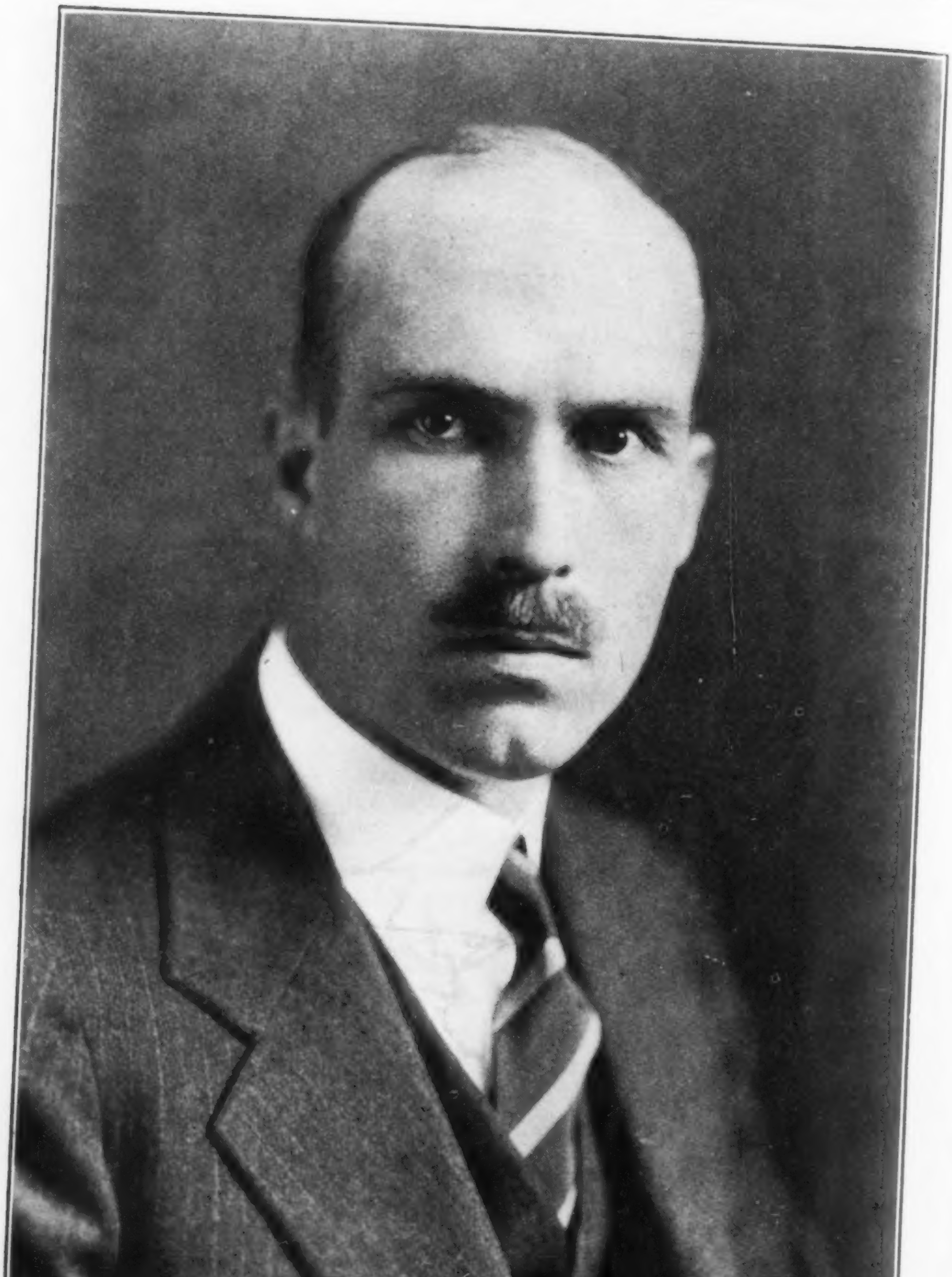
The result of the ballot is as follows:	Votes
For President—1 year—J. Fletcher Harper	1658
For Vice-President—1 year—F. G. Hughes	1660
For Secretary—2 years—W. H. Eisenman	1660
For Member of Board—2 years—L. D. Hawkridge	1658
For Member of Board—2 years—J. H. Nead	1660
Scattering votes—President	3
Scattering votes—Vice-President	1
Scattering votes—Secretary	1
Scattering votes—Directors	4
Defective votes	27

Respectfully submitted,

W. P. SYKES.
D. M. GURNEY.
C. G. SHONTZ, *Chairman.*

The Board of Directors of the Society is composed of the newly elected officers, Dr. Zay Jeffries, treasurer, and the two directors, R. G. Guthrie and Hyman Bornstein, who hold over on the Board. R. M. Bird, past president of the Society, remains on the Board for one year. These new elections became effective January 1, 1927.

Portraits of the Society's officers appear on the following pages.

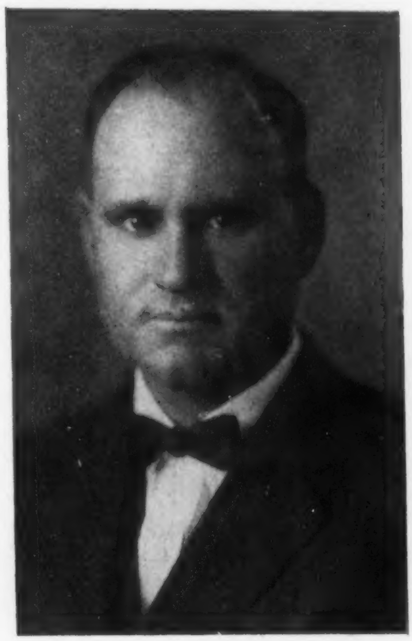


J. FLETCHER HARPER
President, American Society for Steel Treating

R. M. BIRD
Director of the Society

F. G. HUGHES
Vice-President of the Society

W. H. EISENMAN
Secretary of the Society



DR. ZAY JEFFRIES
Treasurer of the Society

R. G. GUTHRIE
Director of the Society

HYMAN BORNSTEIN
Director of the Society

J. H. NEAD
Director of the Society

L. D. HAWKRIDGE
Director of the Society

WASHINGTON AND THE WINTER SECTIONAL MEETING

FROM present indications, the Winter Sectional Meeting which is to be held by the American Society for Steel Treating at Washington, D. C., January 20-21 1927, will be one of the most interesting and best attended of all sectional meetings held by the Society. The headquarters hotel is the Mayflower.

Arrangements have been consummated for the board of directors' meeting and the various committee meetings to be held

The National Capitol

on the day preceding the official opening of the meeting proper and seven papers have been scheduled for presentation at the three technical sessions to be held on Thursday and Friday. The program of papers is given on page 12.

The Early Bird's dinner on Wednesday evening and the banquet on Thursday evening, are scheduled for 6:30 p. m. at the Mayflower, and Cosmos Club, respectively.

Thursday and Friday afternoons will be devoted to inspection trips and interesting tours have been planned for those who

desire to remain in the city on Saturday. It is expected that many of the members and guests will avail themselves of the opportunity to see the magnificent federal buildings, some of the finest in the world, and to become somewhat cognizant of the tremendous business of running the various departments of the government of this country.

Washington has an intellectual charm and an informal aristocratic atmosphere which is perhaps not found in capitals elsewhere in the world. It is a city definitely planned to be the capital of a great nation. Its broad streets and avenues furnish excellent facilities for public demonstrations of all kinds. Its elegant trees, flowers and open green spaces are everywhere prevelant and its magnificent marble buildings are decided civic assets and add to its physical beauty, and make it colorful, which is in marked contrast to the drabness of most large cities.

It is one of the greatest intellectual centers in the world. For here gather together people from every part of the globe intent on studying the latest methods and ascertaining the newest developments in all enterprises known to the genius of man.

To most visitors, the Capitol building is of especial interest for here may be seen the two branches of congress in session, the Supreme Court of the United States sitting in full regalia, Statuary Hall which contains the famous "whispering gallery," many interesting statutes of distinguished men from various states of the union and other art treasures; the Franzoni clock; the rotunda with its allegorical paintings and the Rogers bronze doors which depict the life of Columbus. Here the citizen beholds his government for here are made, interpreted and executed the laws of his Nation. The other buildings such as the Treasury, Patent Office, Bureau of Standards, Army and Navy Buildings and others too numerous to here mention,—these are but elaborations—subsidiaries, to the Capitol which is the embodiment of American patriotism and citizenship.

Those who are interested in novel methods of heating and ventilating large buildings, will find interest in examining the unique method of heat radiation in this building.

Close to the Capitol, is the Library of Congress which is said to be one of the finest interiors in America. The dome which is constructed of copper panelled with gold, may be seen from a

distance and upon approaching the building the bronze Fountain of Neptune attracts the visitor's attention. The three bronze entrance doors symbolic of printing, writing and tradition are well worth close observation.

The entrance vestibule is of white Italian marble, and the ceiling, like the dome, is of 22-karat gold. Further on is the central stair hall, a magnificent interior, said to be the finest

The Library of Congress

entrance hall in the world. It is lined throughout with highly polished Italian marble. A double marble staircase, beautifully decorated with miniature marble figures, leads to the landing on the wall of which is Vedder's Minerva, a mosaic in stone,—brilliant, colorful and symbolic of the wonderful achievements of human imagination and research.

Is is significant that the architects, painters, sculptors and decorators who produced this marvelous building were all American artists.

To the Library of Congress are sent two copies of every publication for copyrighting. And here go each month two copies

of the Transactions of the American Society for Steel Treating to be filed for copyrighting.

One of the most interesting and valuable institutions of learning, research and the spreading of human knowledge, is Smithsonian Institute and National Museum located in the Mall on B Street. Its activities are devoted largely to science, invention and exploration. It issues three publications for the dif-

The Lincoln Memorial

fusion of knowledge, carries on extensive intercommunication with learned societies and individuals and has over 60,000 correspondents scattered over the globe. Congress has by law made this institution the Custodian of National Collections.

For those who are interested in art, the Corcoran and Freer art galleries hold much attraction. The Freer Gallery especially contains much of interest and value to the student of the art of the Far East for here may be seen over 1800 Chinese paintings done between 255 B. C. and the present time. There are also some 800 Japanese paintings; potteries from China, Japan and Korea; stone and wood sculpture and bronzes; East Indian paintings, and Egyptian art works. Admirers of Whistler will be delighted with the Peacock room located in the Freer Gallery.

Southwest from the Capitol, is situated Potomac Park which

stretches along the river for more than two miles and at the upper end of the park stands the magnificent Lincoln Memorial, a great white structure built in the form of a Greek Temple with 36 white marble columns 44 feet high. Truly a symbol of unity of the thirty-six states in the union which Lincoln succeeded in keeping intact. The building is of such excellent proportions that its vast size is lost in its unity and symmetry. Occupying a position of honor, on the axis of the Capitol and Washington Monument, it stands alone in its grandeur with nothing to mar the full view of its loveliness. Alone truly symbolic of the great, silent, lovable man in whose honor it was erected.

Much credit is due to Messrs. Burnham, McKim and Saint Gaudens, three of America's artist geniuses, not only for the exquisite Lincoln Memorial but for their work and artistry in carrying on and elaborating on the early plan of L'Enfant which has always been the basis of the Washington plan of development.

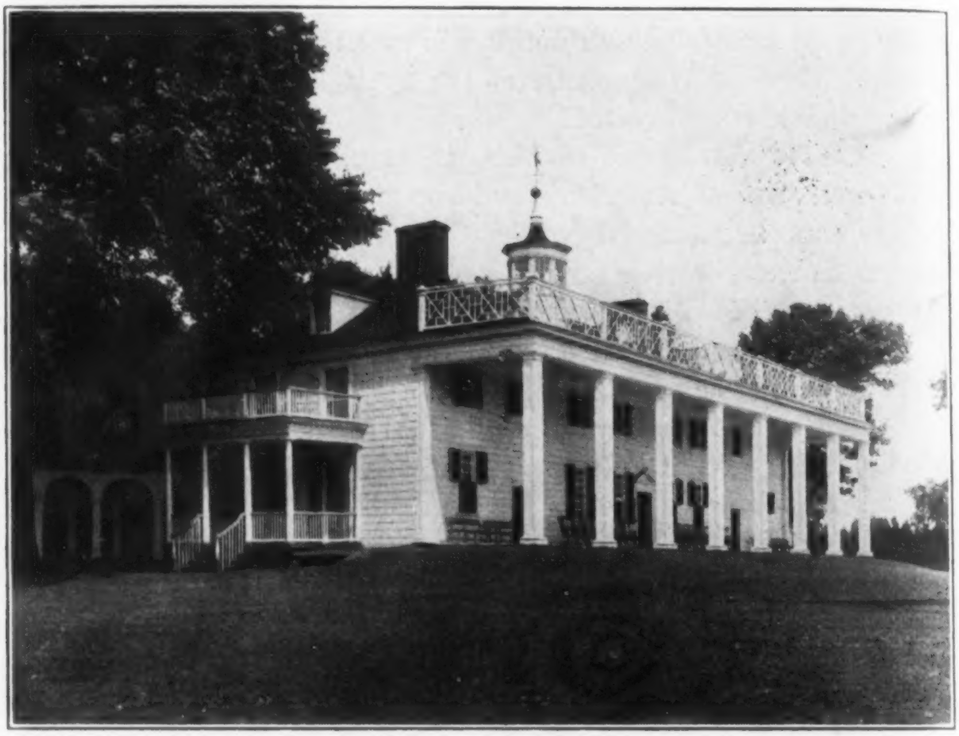
The suburbs of Washington are historical and many interesting short trips may be made.

Close by is Arlington, the National cemetery, situated on the Virginia side of the Potomac. It is one of the largest and most beautiful cemeteries in this country and here lie buried soldiers who fought in all the National wars from the Revolutionary to the World War. It is a shrine of American patriotism and sacrifice. The Memorial Amphitheater was erected as a memorial to the soldier dead and as a suitable place for public services on Memorial day and other holidays commemorating the Nation's dead. Here, too, may be seen the Tomb of the Unknown Soldier, the great dignified, silent tribute to all the soldier dead.

One has not really seen Washington until he obtains a view of it from the Heights of Arlington House, General Lee's former home. This is situated about 200 feet above the shores of the Potomac River. On the further shore of the Potomac rises Georgetown, far to the north are the towers of Soldier's Home and to the south the quaint old city of Alexandria. Alexandria is located eight miles from Washington and was the metropolis of the British Empire in the New World. It is famous for its revolutionary history and here at Carlyle House which was built by the English in 1752, Washington, from records contained in his diary, was a frequent and welcomed visitor. Christ Church at Alexandria was

attended by both Washington and Lee and here also may be seen one of the oldest cemeteries in this country with old tombstones bearing quaint inscriptions and dates long prior to Revolutionary days.

Leaving Alexandria let us finish our journey to Mount Vernon by water where we may get a charming view as we approach the lovely grounds and simple colonial buildings belonging to Martha



Washington's Mount Vernon Home

and George Washington. The home was built in 1743. The estate was purchased by the Mount Vernon Ladies Association in 1858 for $200,000.00. Thus the home and tomb of Washington has added interest for its acquisition is the result of the patriotism, work and vision of the women of America.

One of the most interesting rooms in the Washington home is the kitchen. The various other rooms contain much of interest and many examples of fine Colonial art. Martha Washington's garden is a delight to garden lovers.

The memorial trees near Washington's Tomb, which is a simple structure of brick are of interest,—an elm planted by the Emperor of Brazil in 1876, the British Oak, Concord elm, the

German linden and the Phi Kappa Psi elm are only a few of the historical trees on the grounds.

These are some of the interesting things which may be seen on the special tour which has been planned for Saturday.

So it is in Washington that one may see the results of the whole gamut of man's achievements from the astrophysical observatory to the zoological park. Here to this charming city come scientific experts from all parts of the world to pursue their research and mingle with the intellectual elite. Erudite metal-

The Mayflower

lurgists, physicists, chemists, authorities on all subjects from the inner construction of a base ball, which wins the pennant, to the carburizing of a piece of steel, used in an airplane to carry the glad tidings to the world, may be found carrying on their work in various departments. Yet in one thing all scientists agree, we think, that the greatest element of success is the human element —man himself. We are making men, not things, in this country. Cooperation is one of the great secrets of the success of the people of this mighty nation. One of the first industries to recognize the value of cooperation was the steel industry. It believes firmly in the slogan that what is good for one is good for all. That is the reason of the various meetings throughout the year and that is primarily the purpose of the Winter Sectional Meeting which is to be held in Washington—the coming together of men to give to each other new ideas, inspiration, and extend the hand of fellowship and to help those who have problems which seem difficult, if not almost impossible, to solve. Here will gather men who are

(Continued on Page 14)

PROGRAM FOR WINTER SECTIONAL MEETING, HOTEL MAYFLOWER, WASHINGTON—JANUARY 20-21, 1927

WEDNESDAY, JANUARY 19

9:30 A. M.—Meeting of Board of Directors.

9:30 A. M.—Meeting of Publication Committee, H. M. Boylston, chairman.

6:30 P. M.—Early Bird's Dinner and Theater Party—Mayflower.

THURSDAY, JANUARY 20

Morning Technical Session

8:00 A. M.—Committee A4, A. S. T. M.—H. M. Boylston, Chairman

9:00 A. M. to 10:00 A. M.—Registration.

Chairman: J. F. Harper, Allis-Chalmers Mfg. Co., Milwaukee, Wisconsin

10:00-10:40 A. M.—*Review of the Metallurgical Activities of the Washington-Baltimore District*—Emil Gathmann, president, Gathmann Engineering Company, Baltimore.

10:40-11:20 A. M.—*Wear Resistance of Cutting Edges of Blanking Die Parts and Shear Blades*—W. J. Merten, metallurgical engineer, Westinghouse Electric and Manufacturing Co., Pittsburgh.

11:20-12:00 A. M.—*Iron-Carbon-Vanadium Alloy for Brinell Balls*—G. W. Quick, assistant metallurgist, and L. Jordan, chemist, Bureau of Standards, Washington.

Afternoon Session

1:30 P. M.—Inspection Trip.—U. S. Naval Gun Factory, Washington Navy Yard or Baltimore Copper & Smelting Co.

Evening Session

6:30 P. M.—Banquet, Cosmos Club, Washington.

FRIDAY, JANUARY 21

Morning Technical Session

Chairman: Robert M. Bird, G. F. Pettinos Co., Philadelphia

Vice-Chairman: Dr. H. W. Gillett, Bureau of Standards, Washington

10:00-11-00 A. M.—*Centrifugal Casting of Steel*—Leon Cammen, associate editor of "Mechanical Engineering" and consulting engineer, New York City.

11:00-12:00 A. M.—*Fundamental Research on Nonmetallic Inclusions in Steel*—Dr. C. H. Herty, physical chemist, Bureau of Mines Experiment Station, Pittsburgh.

Afternoon Session

1:30-5:00 P. M.—Inspection Trip.—U. S. Bureau of Standards Research & Testing Laboratories or Crown Cork and Seal Company or Baltimore Metal Lithographing & Stamping Co.

Evening Technical Session

Chairman: Dr. G. K. Burgess, director of Bureau of Standards, Washington

Vice-Chairman: P. E. McKinney, U. S. Naval Gun Factory, Washington

8:00-8:30 P. M.—*Progress in the Study of Normal and Abnormal Steel*—S. Epstein, associate physicist, and H. S. Rawdon, physicist, Bureau of Standards, Washington.

8:30-9:00 P. M.—*Normality of Steel*—J. D. Gat, metallurgical engineer, research department, Central Alloy Steel Co., Canton, O.

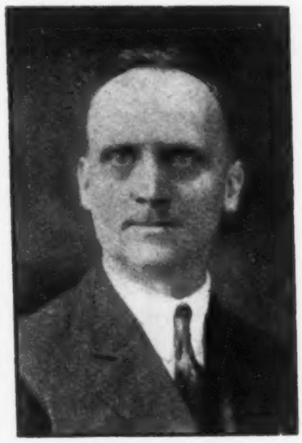
9:00 P. M.—Joint Discussion.

SATURDAY, JANUARY 22

Special Tours of Washington.

EMIL GATHMANN

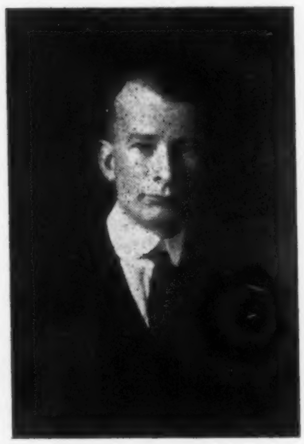
LEON CAMMEN



W. J. MERTEN

J. D. GAT

DR. C. H. HERTY



G. W. QUICK

J. F. HARPER

DR. G. K. BURGESS

R. M. BIRD

SOME OF THE AUTHORS AND CHAIRMEN PARTICIPATING IN THE TECHNICAL SESSIONS AT THE WINTER SECTIONAL MEETING
WASHINGTON, JANUARY 20 AND 21, 1927

interested in steel, its manufacture, heat treatment and uses. They will add to the knowledge and wealth of the world and to the well-being, comfort and happiness of all human beings. It will, indeed, be the beginning of a happier and better new year.

TECHNICAL PAPERS PROGRAM

FROM the program as printed on page 12 it will be observed that there are seven papers scheduled on the technical program which has been divided into three sessions—Thursday morning, Friday morning and Friday evening.

A brief abstract of each of these papers is as follows:

"*Review of Metallurgical Activities of the Washington-Baltimore District.*" By Emil Gathmann, president Gathmann Engineering Company, Baltimore.

Mr. Gathmann presents a general review of the historical and up-to-date metallurgical activities in the territory now embraced by our Washington-Baltimore Chapter. When the research work of the Bureau of Standards and the Naval Gun Factory is taken into consideration, the present-day metallurgical activities of this district may be said to cover all fields the world over in which the art of metallurgy is known or practiced.

"*Wear Resistance of Cutting Edges of Blanking Dies and Shear Blades.*" By W. J. Merten, metallurgical engineer, Westinghouse Electric and Manufacturing Co., Pittsburgh.

Mr. Merten shows and discusses the effect of shearing and blanking of sheets and plates upon the cutting edge of shear blades and die parts when these sheets and plates are covered with hammer or roll scale (Fe_3O_4), or when an intensely hard and abrasive constituent irregularly but profusely scattered or dispersed through it, such as iron silicide (FeSi) in silicon sheet. He gives a review of the various methods employed to hinder fragmentation of the hard crystals and inbed them when fractured so as to avoid and neutralize their grinding effect upon the cutting edge. He discusses the utility of uniformly hard die parts for burrless blanking and shear cutting. He has also discussed the importance of die design for obtaining long life of the cutting edge, which is equivalent to the large scale production of a punching free from burrs. Severe deformation of the crystal structure by the use of soft punch parts not evidenced by burr formation is also illustrated.

"*Iron-Carbon-Vanadium Alloy for Brinell Balls.*" By G. W. Quick, assistant metallurgist, and L. Jordan, chemist, Bureau of Standards, Washington, D. C.

The authors discuss a special iron-carbon-vanadium alloy of about 2.9 per cent carbon and 13 per cent vanadium having been experimentally used for Brinell balls in the testing of steels of such hardness as cause ordinary Brinell balls to deform both elastically and plastically. These special balls, heat-treated, work-hardened, and tested against steels of approximately 700 Brinell, flattened about one-half as much as Hultgren balls and one-fifth as much as ordinary Brinell balls. The opinion that the hardness obtainable in a plain carbon steel by combined heat treatment and cold-work is the maximum hardness to be secured by such treatments, irrespective of the composition of the steel, is shown to be untrue. The difference in flattening between iron-carbon-vanadium and Hultgren balls does not, however, appreciably affect the hardness number of steels up to 700 Brinell.

"*Centrifugal Casting of Steel.*" By Leon Cammen, associate editor of Mechanical Engineering and consulting engineer, New York.

The first part of the paper deals with the more familiar subject of centrifugal tube casting, which is a comparatively old art, and shows its present and prospective field of application and limitations, particularly where centrifugal tube casting comes into competition with the piercing process. The second part of the paper is devoted to the new art of centrifugal bar casting, affecting the entire steel industry. Its importance lies in its ability to produce metal of better quality at a cost estimated to be from $3.50 to $8.50 per ton lower than present methods. The mechanical and metallurgical features of the process are explained, and the machinery employed is described and illustrated in some detail.

"*Fundamental Research on Non-Metallic Inclusions in Steel Manufacture.*" By C. H. Herty, Jr., physical chemist, U. S. Department of Commerce, Bureau of Mines Experiment Station, Pittsburgh.

The author classifies the problems encountered in the making of steel and points out that the field for fundamental research in its manufacture is astounding in its magnitude and intricacies, and that any discussion of the various processes of manufacture and the problems which arise becomes exceedingly involved and voluminous. The writer has therefore limited his paper to a consideration of the fundamental research which deals primarily with slag-metal reactions, giving particular attention to the formation and elimination of nonmetallic inclusions formed from manganese, silicon and aluminum. He is of the opinion that the problem of solid nonmetallic inclusions in steel is an important one to the manufacturer of this commodity and sets forth the two main lines along which, in his estimation, it is necessary to work to eliminate it. The author hopes that general cooperation along this line of research will result in a solution of the momentous question of "solid nonmetallic inclusions in steel."

"*Progress in Study of Normal and Abnormal Steel.*" By S. Epstein, associate physicist, and H. S. Rawdon, physicist, Bureau of Standards, Washington, D. C.

The authors discuss and define the meaning of the terms, normal and abnormal steel. The characteristics of the normal and abnormal structure in carburizing steel and tool steel are illustrated. It is shown that under certain quenching conditions abnormal steel is more prone to give soft spots than normal steel, but that with drastic quenching in brine or in a sodium hydroxide solution, it is possible to completely prevent the formation of soft spots in both normal and abnormal steel. It is shown that normality and abnormality have their origin in the deoxidation procedure of steel making and that in particular additions of aluminum and ferrovanadium in the mold produced abnormality.

"*Normality of Steel.*" By J. D. Gat, metallurgical engineer, research department, Central Alloy Steel Corporation, Canton, O.

This paper was written in order to bring about better understanding of the term "normality of steel" and properties possessed by steels classified as abnormal. After conducting some experiments to demonstrate the behavior of steels having different grain size and amounts of segregated cementite, the writer dwells on the properties of "cementitic lining" present in abnormal steels and comes to the conclusion that resistance to uniform hardening is caused by high oxygen content forming a eutectoid alloy with the constituents of austenite.

All of these papers have been preprinted and are available to all members of the Society upon request to the National Office, 4600 Prospect Avenue, Cleveland, Ohio.

THE QUARTER-CENTURY ANNIVERSARY CELEBRATION OF THE BUREAU OF STANDARDS

At the celebration of the twenty-fifth birthday of the United States Bureau of Standards held in Washington on December 4, 1926, many distinguished men and women were present to do honor to the occasion.

During the day, the staff kept "open house" and welcomed their friends and guests who availed themselves of the opportunity of visiting the Bureau and becoming acquainted with the work that it is doing. The beautiful and efficient laboratories were open for inspection and visitors were told of the various researches in progress in these laboratories.

The dinner given by the staff in the evening at the New Willard Hotel was attended by about 450 members and guests.

Dr. Burgess, the Director of the bureau acted as toastmaster, and men who are prominent in the affairs of the Bureau and who were instrumental in developing it to its present capacities, gave interesting and inspirational talks on what the Bureau had contributed to the welfare of this country since its inception, twenty-five years ago.

The Honorable Herbert Hoover, secretary of commerce administering the Bureau, in making the first address on the program set forth how the Bureau had, through its development of science, especially along the field of the development of standards, contributed much to the well-being and wealth of this nation. He particularly stressed the value of the development of precision both in

thought and in its application to measurement. He is of the opinion that precision of thought is of greatest fundamental value to the development of science, and that through science may be developed the greater use of resources and by the use of precision machinery man has more leisure in which to develop and enjoy the finer things in life and thus constantly raise the standard of living.

In concluding, Mr. Hoover said that he is of the opinion that even though our population is increasing rapidly, the standard of living may be maintained and even raised if agencies such as the Bureau of Standards are supported in the excellent work they are carrying on.

In this connection it might be of interest to know that the appropriation of the Bureau of Standards is about two and a quarter millions of dollars per year and that this is far in excess of the income of most large universities. This would indeed indicate that much importance is attached to the work of the Bureau in furthering the scope of science indeed it is indicative of the value placed upon the development of science to affairs pertaining to the progress of the world as it is more than national—it is international in its scope.

Dr. F. A. Wolf, who is a charter member of the Bureau, gave a history of its activities from its early beginnings when it was a part of the Coast Survey down through the time it fought for its very existence and up to the present time.

G. B. Cortelyou, a former secretary of commerce, in his talk lauded the men who had carried on the splendid work of this institution. He called especial attention to the men who quietly worked at their desks and in the workshops—unknown, unsung and unhonored by the public whom they so faithfully serve. He also touched upon the tremendous scope of the work of this institution and pointed out how it touched every phase of industrial life.

Dr. S. W. Stratton, a former Director at the Bureau, called attention to the cooperation existing between the Bureau and the other departments of the government.

It will be the privilege of the members and guests of the American Society for Steel Treating in attendance at the Winter Sectional Meeting to visit the laboratories of the Bureau of Standards on Friday afternoon, January 21.

THE DECOMPOSITION OF THE AUSTENITIC STRUCTURE IN STEEL*

By Ralph L. Dowdell and Oscar E. Harder

Preface

THIS study on the decomposition of the austenitic structure in steels has been arranged under six main divisions or parts, and are to appear in Transactions serially. The divisions are as follows:

I. The decomposition of austenite during quenching.
II. The decomposition of austenite in liquid oxygen.
III. The effect of tempering (drawing) temperature on the decomposition of austenite.
IV. The effect of stress on the tempering changes and decomposition of austenite.
V. X-ray studies on the decomposition of the austenitic structure in steel.
VI. Proposed theory of the hardening and tempering of steel.

It is believed by the writers that a brief summary of the work done by previous investigators is advisable before entering into the written discussion of these articles. A large amount of research work has been accomplished in this field, but only the researches which the writers believe to be of most importance have been included in this preface.

Acknowledgment

Acknowledgment is gladly made to E. W. Davis, superintendent of the Minnesota School of Mines Experiment Station, and the employees of his chemical staff for the analytical work, and to Elmer H. Smith of the Smiths Inventions, Inc., Minneapolis, for his generous gifts of liquid oxygen.

The writers also wish to thank the following persons, all of

*This and the following articles on The Decomposition of the Austenitic Structure in Steel are based on a manuscript submitted by Ralph Lewis Dowell in partial fulfillment of the requirements of the Graduate School of the University of Minnesota for the degree of Doctor of Philosophy. O E. Harder, in charge of research.

A paper presented before the eighth annual convention of the Society, Chicago, September 20 to 24, 1926. Of the authors, Dr. R. L. Dowdell is assistant professor of metallography and Dr. O. E. Harder is professor of metallography, University of Minnesota, Minneapolis.

whom are associated with the University of Minnesota, for aid in the work: Miss Carrie Green, David Crowther, Thomas P. Hughes, Professor George C. Priester, Fred Teal, and Dr. L. J. Weber.

E. C. Bain very kindly supplied samples of the "high chromium" steel which he had used in one of his researches, (TRANSACTIONS, A. S. S. T., vol. 5, p. 89, 1924).

WORK BY PREVIOUS INVESTIGATORS

1. MICROCONSTITUENTS.—The phases which are known to exist in the iron-carbon system have been identified and their properties studied by many investigators. Certain microconstituents are now generally recognized and will be discussed below.

a. Ferrite.—The term ferrite was coined by Howe to represent the nearly pure iron matrix of a thoroughly annealed low carbon steel which is stable at room temperature. In plain carbon steels the ferrite probably contains small amounts of silicon, manganese and carbon in a state of solid solution.

Ferrite is readily etched in the common steel etching reagents and on mild etching exhibits a grain structure similar to pure metals. On continued etching this practically pure iron (alpha iron) is darkened and develops many cubic "etching pits" indicating its crystallinity.

Hull[1] determined the lattice parameter on fine filings of pure electrolytic iron and also on a fine powder obtained by the reduction of Fe_2O_3 in hydrogen and found that these alpha irons have a body-centered cubic lattice with a parameter of 2.86 Å units (one Å unit is equal to 10^{-8} cm.).

Wever[2] found that the alpha lattice for electrolytic iron and annealed steels of 0.07, 0.56, and 0.86 per cent carbon all gave the same lattice parameter of 2.863 Å. There is a magnetic change in ferrite at about 1410 degrees Fahr. (767 degrees Cent.) and above this temperature it has sometimes been referred to as beta ferrite but later researches, particularly X-ray analysis, indicate that there is no space lattice change at this temperature.

b. Cementite.—The term cementite was also coined by Howe to represent the hard and brittle white constituent to which the formula Fe_3C has been given.

[1] *Physical Review*, 1917, Vol. 10, No. 6, pages 661-696.

[2] *Zeitschrift für Electrochemie*, 1924, Vol. 30, page 370.

Honda[3] rediscovered and studied a critical point in cementite which had previously been noted by Mme. Curie and which is known as the Curie A_0. This point was found by magnetic analysis and occurs during heating or cooling at 420 degrees Fahr. (215 degrees Cent.) Honda states that this transformation is similar to the A_2 in not being a change of phase and that it always "terminates or commences at the same temperature."

Westgren and Phragmen,[4] showed that the X-ray crystallogram of cementite contained a large number of lines and the space lattice was practically unsolvable by the powder method. The crystallogram of cementite from annealed steel, unannealed steel (lamellar pearlite), cast iron, spiegeleisen, and cohenite (cementite from meteorites) all gave the same pattern. On measuring a plate of spiegeleisen of 13.1 per cent manganese, 5.1 per cent carbon and 9.05 per cent silicon with a goniometer, the crystal lattice was found to be that of an orthorhombic parallelopiped with an axial ratio of:

$$a_1 : a_2 : a_3 = .673 : .758 : 1$$
$$a_1 : a_2 : a_3 = 4{,}518\ \text{Å} : 5.069\ \text{Å} : 6.736\ \text{Å}$$

From rotational crystallograms of cementite by the Laue method it was found that the crystal contains four molecules of Fe_3C and these data give a calculated density of 7.68 ± 0.05.

c. Austenite.—The microconstituent austenite was named by Osmond[5] in honor of the researches of Roberts-Austen one of the pioneers in the field of physical metallurgy. Researches on austenite, using the X-ray method of analysis, by Westgren,[6] Westgren and Phragmen,[7] Jeffries and Archer,[8] and Bain,[9] indicate that austenite is a solid solution of carbon in gamma iron.

More recently Westgren and Phragmen[10] concluded from

[3] *Science Reports*, Tohoku Imperial University, 1922, Vol. XI, No. 2, pages 119-130.

[4] *Journal*, Iron and Steel Institute, 1924, Vol. 109, pages 159-174.

[5] *Bulletin de Societié d'Encouragement*, Vol. X-4, 1905, page 480.

[6] *Journal*, Iron and Steel Institute, 1921, Vol. 103, No. 1, pages 303-325.

[7] *Journal*, Iron and Steel Institute, 1922, Vol. 105, No. 1, pages 241-262.

[8] *Chemical and Metallurgical Engineering*, 1921, Vol. 24, page 1057.

[9] *Journal*, American Institute of Mining and Metallurgical Engineers, New York Meeting, February 1924.

[10] *Journal*, Iron and Steel Institute, 1924, Vol. 109, pages 159-174.

their researches that the lattice dimensions of austenite increase in size with rising carbon content; in this respect austenite appears to differ from ferrite. They also postulate that this austenitic solid solution is not formed by simple substitution of metal atoms by carbon atoms in the gamma face-centered cubic lattice, but that the carbon atoms are situated in the interstices between the metal atoms. The above theory was advanced because the density as calculated from X-ray data on an austenitic manganese steel showed a value of 7.36 if the carbon atoms replace an equal number of the metal atoms, and a value of 7.83 when the carbon atoms occupy the interstices between the metal atoms. This last value was checked exactly by the regular density determinations. Westgren and Phragmen have also made X-ray measurements at elevated temperatures. Electrolytic gamma iron interferences were determined at temperatures of 1100 and 1425 degrees Cent. and found to be 3.63 Å and 3.68 Å units respectively. Pure iron at 1472 degrees Fahr. (800 degrees Cent.) gave 2.90 Å units. They also found that the side of the elementary cube of a 25 per cent nickel steel containing 0.24 per cent carbon was 3.56 Å when water quenched from 1832 degrees Fahr. (1000 degrees Cent.) A 22.3 per cent nickel steel containing 1.18 per cent carbon showed 3.64 Å. From these results they concluded that carbon increased the lattice.

Wever has shown[11] that for a series of manganese steels varying from high manganese with low carbon (19.08 per cent manganese, 0.30 per cent carbon) to low manganese with high carbon (2.06 per cent manganese, 1.90 per cent carbon) the lattice parameter of the gamma solution varied from 3.597 to 3.643 Å. The specific volume of the series varied from 0.1262 to 0.1288 for the high and low manganese steels respectively.

d. Martensite.—The microconstituent martensite was named by Osmond in honor of Professor Martens. Osmond[12] originally applied the term hardenite to the microconstituent that separated from the austenite when an austenitic structure was submerged in liquid oxygen. This structure is now generally known as martensite.

[11] *Zeitschrift für Electrochemie*, 1924, Vol. 30, page 376.

[12] Bulletin de la Societié d'Encouragement, Vol. X-4, 1905, page 480.

In Stead's[13] translation of Osmond's work the following statement is made: "In liquid air austenite is transformed with increase of volume into hardenite. After a few minutes the polished specimen containing austenite swells in slight relief above the hardenite." Osmond defined hardenite as a saturated martensite which had a mesial rib that etched more deeply. At the present time most metallurgists associate these needles with martensite.

The theory has been advanced by Jeffries and Archer[14] that freshly formed martensite consists of a solid solution of carbon in very fine grained alpha iron. They claim that the hardness is due principally to the grain refinement of the ferrite but partly to the carbon.

In a recent questionnaire sent out by Sauveur[15] and answered by twenty-three metallurgists, it seems that there is a considerable difference of opinion as to whether carbon or carbide is present in austenite and martensite. The experimental evidence on the question is exceedingly small and this state of information is probably responsible for the widely different opinions.

However, Westgren,[16] and Westgren and Phragmen,[17] state from X-ray evidence that in martensite, iron is in the form of its alpha modification and that the diffused character of the lines in the crystallograms gives important information as to the structure of martensite because Scherrer[18] has shown that the lines of a Debye-Scherrer crystallogram get broader and more diffused in proportion as the crystal powder is more finely divided. The lines from a gold colloid seem to resemble martensite in breadth.

Westgren and Phragmen[17] reported lattice parameters of 2.90 Å for a 1.98 per cent carbon steel quenched in water from 1832 degrees Fahr. (1000 degrees Cent.) and from 2012 degrees Fahr. (1100 degrees Cent.) On quenching the above steel from 1400 degrees Fahr. (760 degrees Cent.) the martensite had a value of 2.88 Å which indicated that the martensite contained alpha iron.

[13]Microscopic Analysis of Metals—Second Edition, 1913. Griffin & Co., London.

[14]*Chemical and Metallurgical Engineering*, 1921, Vol. 24, page 1057.

[15]Paper No. 1532-C issued with Mining and Metallurgy, February 1926.

[16]*Journal*, Iron and Steel Institute, 1921, Vol. 103, No. 1, pages 305-325.

[17]*Journal*, Iron and Steel Institute, 1922, Vol. 105, No. 1, pages 241-62.

[18]*Physical Zeitschrift*, Vol. 18, 1917, pages 291-483.

Another plain carbon steel of 1.25 per cent carbon showed a value of 2.88 Å when quenched in water from 760 degrees Cent. These results seem to indicate that the parameter depends upon the amount of carbon in solution and the quenching temperature.

Westgren[19] submerged the austenitic manganese and nickel steels (2 millimeter rods), previously mentioned, in liquid oxygen. The manganese steel showed no change when X-rayed, but the nickel steel was materially changed. He described the pattern as follows: "the gamma lines still existed but were diffuse and unsharp, indicating that the steel had become extremely finely crystalline in structure." He also stated that alpha iron produced by this treatment had a lattice parameter of only 2.81 Å while the gamma lattice changed from 3.58 to 3.54 Å. Microscopic examination of the specimen showed that about one-half of the original austenitic structure was changed to the white lance shaped needles.

Fink and Campbell[20] have reported in drastically quenched eutectoid and hypereutectoid carbon steels a crystal structure which seemed to be body-centered tetragonal in which structure the average of (a) was 2.85 Å and the value of (c) 3.02 Å. These values correspond to an axial ratio of 1.06. Bain, however, discussed the paper by Fink and Campbell and referred to his previous lectures on the mechanism of the allotropic change from the gamma to the alpha lattice and called attention to the fact that the body-centered arrangement in the gamma lattice is at first tetragonal with an axial ratio of 1.414 and suggested the possibility that the final condition in martensite is an incomplete transformation to the "perfectly cubically crystallized alpha iron." It is interesting to note that the figures by Fink and Campbell show that the a axis has increased from 2.55 to 2.85 Å while the c axis has decreased from 3.60 to only 3.02 Å.

c. Troostite.—Troostite was named by Osmond, in honor of Professor Troost, to represent the dark etching constituent found in quenched and mildly tempered steels. Hanemann, Lucas, and others have shown micrographs of two varieties which are found in both quenched and tempered steels. One variety is acicular, in this regard similar to martensite, but etches very dark, while the other forms irregular rounded patches. It is generally ac-

[19]*Journal*, Iron and Steel Institute, 1921, Vol. 103, No. 1, pages 717-754.

[20]TRANSACTIONS, American Society for Steel Treating, 1926, Vol. 9, No. 5, pages 717-754.

cepted that troostite forms in carbon steels on tempering martensite in the range 212-500 degrees Fahr. (100-260 degrees Cent.).

Benedicks[21] stated that "troostite as regards electrical resistance and specific volume behaves as pearlite;" i. e. as a mechanical mixture of iron and cementite.

Jeffries and Archer[22] have stated that in the tempering of martensite, ferrite grain growth, the carbide precipitation, and growth of cementite particles take place. The ferrite grain growth causes softening while the Fe_3C precipitation causes hardening.

Some of the investigators agree in the statement that there is a progressive change involved when a white or a light colored acicular martensite is tempered. In this progressive tempering below the Ac_1 transformation, there are probably two important reactions: first precipitation, and second coalescence of carbide particles. As revealed by microscopic and physical tests, the carbide particles coalesce to larger and larger particles until the distinct spheroidal form can be easily identified under the microscope.

In 1906 Heyn and Bauer[23] discussed osmondite and suggested that it be placed between troostite and sorbite. According to the definition given by the authors, it is merely a state of the steel exhibiting a maximum content of troostite and thereby presenting a maximum speed of etching or solution in acids. Frankel and Heymann[24] state that in the course of time, from the basis of kinetics, the presence of an iron carbide of high carbon content (FeC_{8-10}) will probably be established. However, it is believed by most metallurgists that osmondite and troostite are essentially the same and contain the same carbide, Fe_3C.

2. Effect of Quenching on the Austenitic Structure.—Many investigators have shown that martensite needles, fairly wide and flat, can be formed in an austenite groundmass by quenching high carbon steels from a rather high temperature. It is the writers' opinion that these so-called needles are really plates formed along the octahedral slip planes of the austenite which appear on a polished and etched surface either as narrow or

[21] *Journal,* Iron and Steel Institute, 1908, No. 2, Part 2, pages 217-256.

[22] *Chemical and Metallurgical Engineering,* 1921, Vol. 24, page 1057.

[23] *Stahl und Eisen,* 1906, page 782; *Revue de Metallurgie,* 1911, Vol. 8, page 417.

[24] *Zeitung fur Anorg. Chemie,* 1924, Vol. 134, pages 137-171.

wide plates which most frequently form an angle of 60 or 120 degrees to each other. If the carbon content is around 1.7 per cent and the quenching temperature in the neighborhood of 2012 degrees Fahr. (1100 degrees Cent.), it will be found that at room temperature there will be roughly equal amounts of martensite and austenite by volume, the austenite being the groundmass.

Benedicks[25] reported that the natural color of this needle or lance shaped martensite was slightly darker than the austenite in a polished specimen. If the specimen was allowed to stand in the air the austenite was found to be rusted while the martensite remained untouched. This agrees with Osmond's[26] conclusion that, on etching, martensite is whiter than the austenitic groundmass which usually etches with a yellowish tint.

In Osmond's[26] classical work on the "Microstructure of Carbon Steels," it was stated that "the mechanical pressure together with osmotic pressure, may be the determining factor in the occurrence of austenite." This conclusion was based upon quenching tests.

Maurer[27] in 1908 reported an investigation similar to the work of Osmond and stated that on cooling the austenite passes to a martensitic state which is different from that which is produced on tempering.

In 1912 Hanemann[28] quenched a carbon steel of 1.79 per cent carbon with 0.6 per cent manganese. After quenching the specimen was cut in two. One piece was submerged in liquid air while the other remained as quenched. Upon etching the submerged piece he found that some of the needles etched darker and some lighter than the groundmass of austenite while the piece not submerged showed only the dark needles. He concluded that the dark needles were in the tempered condition and found that they were etched below the surface of the austenite while the "whitish light blue" needles were in relief in the light yellow groundmass of austenite.

Bain and Jeffries[29] stated that a high speed steel quenched

[25] *Journal,* Iron and Steel Institute, 1908, No. 2, Part 4, pages 217-56.

[26] Bulletin de la Societie d'Encouragement 4, 1905, Vol. 10, page 480.

[27] *Revue de Metallurgie* Memoirs, 5, 1908, pages 715-750.

[28] *International Zeitung fur Metallographie,* 1912-13, Vol. 3, pages 127-41.

[29] *Iron Age,* 1923, Vol. 112, page 805.

from 2350 degrees Fahr. showed the alpha and gamma patterns in equal intensity but on rapidly immersing the specimen in liquid air (twenty cycles from room temperature to —300 degrees Fahr. (—180 degrees Cent.) there was no observable effect on the austenitic content of the steel or on the intensity of the patterns.

Honda and Idei[30] and Bain[31] have reported the spontaneous formation of martensite from austenite at room temperature.

Hanemann and Schrader[32] recently stated that they rapidly quenched and immediately polished a steel of 1.52 per cent carbon. After a short interval at room temperature, martensite appeared here and there in relief on the specimen.

Hanemann[33] stated that since the martensite (light colored needles) which was formed in liquid air formed from the austenite, it was believed that the same thing happened in quenching because here also the martensite separates out in the Widmanstatten form along the octahedral slip planes of the austenite. Specific gravity determinations on eight-gram specimens showed a decrease of approximately 0.1 in density after the specimens were submerged in the liquid oxygen. He stated that the density decrease was due to the martensite formed which had the largest volume of the microconstituents. He also stated that if the martensite needles produced in liquid air were tempered, they showed a carbon content considerably less than the mother austenite.

In earlier work Hanemann[34] noted that when a 1.5 per cent carbon steel containing 0.3 per cent manganese was quenched from a temperature between 1922-2192 degrees Fahr. (1050-1200 degrees Cent.), the middle of the piece contained some wide needles of martensite while towards the edge they were more numerous and right on the edge the greatest amount of martensite predominated. He concluded that this edge structure was due to decarburization and did not mention the stress factor.

Rawdon and Epstein[35] stated that the coarseness of the martensitic structure appeared to be determined almost entirely by the

[30]*Science Reports*, Tohoku Imperial University, 1920, Vol. 9, pages 491-507; Ibid 1925, Vol. 14, pages 165-72.

[31]*Chemical and Metallurgical Engineering*, 1922, Vol. 26, page 543.

[32]TRANSACTIONS, American Society for Steel Treating, 1926, Vol. 9, No. 2, pages 169-232

[33]*International Zeitung für Metallographie*, 1912-13, Vol. 3, pages 127-141.

[34]*Stahl und Eisen*, 1912, Vol. 32, page 1397.

[35]*Scientific Paper* of U. S. Bureau of Standards, No. 452, 1923.

quenching temperature. This work was recently confirmed by Whiteley[36] who stated that the size of the crystallites of martensite increased with the grains from which they were formed.

Dejean,[37] Portevin and Garvin,[38] Chevenard,[39] and others have shown that when a high carbon steel is rapidly quenched the normal Ar_1 transformation is lowered to a temperature of 572 degrees Fahr. (300 degrees Cent.) and below. This transformation Portevin called Ar″ and considered it to represent the formation of martensite from austenite. This transformation is accompanied by an evolution of heat and an increase in volume.

Portevin and Garvin[38] found that in quenching eutectoid steels the cooling rate required for the retention of martensite (greatest hardness) was less drastic than for either hypo- or hypereutectoid steels. They found that the critical rate of quenching (T) was 6.9 seconds for cooling through the range 1292-392 degrees Fahr. (700-200 degrees Cent.) for a steel containing 1.07 per cent carbon and 0.08 per cent manganese when quenched from an initial temperature of 1382 degrees Fahr (750 degrees Cent.). If the rate of cooling was slower a critical point designated as Ar′ occurred at about 1202 degrees Fahr. (650 degrees Cent.) and the centers of specimens over 14 millimeters in diameter contained troostite. If the rate of cooling was faster than 6.9 seconds the point Ar″ of smaller magnitude than Ar′ was encountered at about 572 degrees Fahr. (300 degrees Cent.) and the structure consisted almost entirely of coarse white needles in a groundmass believed to be austenite.

Honda[40] assumes that austenite decomposes on cooling according to the "stepped" reaction:

$$\text{Austenite} \rightarrow \text{Martensite} \rightarrow \text{Pearlite}$$

On cooling a carbon steel in air the end point, pearlite, must have gone through martensite. Honda includes troostite and sorbite in his term pearlite.

[36]*Journal*, Iron and Steel Institute, 1925, Vol. 111, No. 1, pages 315-38.

[37]*Revue de Metallurgie*, 1917, Vol. 14, pages 641-75.

[38]*Journal*, Iron and Steel Institute, 1919, Vol. 99, pages 469-563.

[39]*Revue de Metallurgie Memoirs*, 1919, Vol. 16, pages 17-79.

[40]*Science Reports*, Tohoku Imperial University, 1925, Vol. 14, No. 2, pages 165-72.

Mathews[41] reported that in a series of chromium and tungsten magnet steels and other alloy steels the magnetic hardness (coercive force) is greater after oil quenching than after water quenching while the scleroscope hardness is less after oil quenching. This indicated more austenite after oil quenching so he carried out the following confirmatory experiments.

Some of his specific gravity determinations are given in the following tabulated data:

Composition of Steel						Specific Gravity After Quenching	
C	Si	Mn	Cr	Ni	W	Oil Quench	Water Quench
0.91	0.25	0.34	2.16	...	...	7.8548	7.8416
0.91	0.25	0.34	2.16	...	...	7.7996	7.7861
0.84	0.20	0.47	2.96	...	...	7.8371	7.8302
...	...	...	...	...	5.00	8.1292	8.1015
...	...	...	2.00	1.00	...	7.8255	7.8177
...	...	...	2.00	...	1.00	7.8755	7.8580

The following data, also from Mathews, show how the magnetic properties are affected by quenching specimens of magnet steel of 0.81 per cent carbon with 2.91 per cent chromium in water and in oil. All sizes were turned from the same bar of 3/4 inch stock.

	Quenched from 1525 degrees Fahr. (830 degrees Cent.) in Oil			Quenched from 1525 degrees Fahr. (830 degrees Cent.) in Water		
Diam. of Section	3/8″	1/2″	11/16″	3/8″	1/2″	11/16″
B_{max} H=300	15400	15400	13600	16600	16600	15500
B_r	9650	9380	8780	10600	10400	10300
H_c	60.3	62.2	66.0	55.2	58.1	58.8
B_r/H_c	160	151	133	192	179	175
After 2 hours in liquid oxygen						
B_r (change)	+6%	+8%	+14%	+1%		+2%
H_c (change)	−1%	−2%	− 7%	+		+

Mathews' conclusion regarding greater austenitic retention after oil quenching was verified by microscopic examination by Lucas and X-ray tests by Bain on the same steels and their results were included in his paper.[42]

Scott[43] performed some interrupted quenching experiments by

[41] *Journal*, Iron and Steel Institute, 1925, Vol. 112-2, pages 299-312.
TRANSACTIONS, American Society for Steel Treating, 1925, Vol. 8, page 565; *Mining and Metallurgy*, No. 1450-C, April, 1925.

[42] Mining and Metallurgy Reprint, No. 1450-C, April, 1925.

[43] Discussion of paper by Hanemann and Schrader, TRANSACTIONS, American Society for Steel Treating, 1926, Vol. 9, page 239.

cooling first in oil down to slightly above Ar″ and then in air until room temperature was reached, and reported a marked increase in the amount of austenite.

Neuthen[44] found the heat of the A_3 transformation in pure iron to be 5.6 calories per gram of iron while Yameda[45] found the heat of transformation of austenite to martensite to be 5.7 calories per gram for a eutectoid steel. Honda[46] stated that the "first change of the A_1 transformation is in reality the A_3 transformation and hence the heat of this transformation, austenite to martensite, must be equal to that of the A_3 in pure iron with a small allowance for the dissolved carbon atoms." Schneider[47] found, however, that the heat effect during the formation of martensite (quenching) was less than that at $Ar_{1\text{-}2\text{-}3}$. This is what would be expected because a slight austenitic groundmass probably always remains after quenching, and none of the exothermic reactions at $Ar_{1\text{-}2\text{-}3}$ is completed.

Heindlhofer and Wright[48] found that in quenching ball bearing steels of 0.55-0.71 per cent chromium and 0.98-1.06 per cent carbon a lower density was obtained from the higher quenching temperatures, 1680-1750 degrees Fahr. (915-950 degrees Cent.), as compared with the lower quenching temperatures, 1472-1590 degrees Fahr. (800-865 degrees Cent.). Also oil quenching a $\frac{9}{16}$-inch ball of these steels from 1590 degrees Fahr. (865 degrees Cent.) and 1750 degrees Fahr. (950 degrees Cent.) gave densities of 7.790 and 7.766 respectively, while when ½-inch balls were quenched in water from 1472 degrees Fahr. (800 degrees Cent.) and 1680 degrees Fahr. (915 degrees Cent.) densities of only 7.755 and 7.745 respectively were obtained.

Brush,[49] and Brush, Hadfield and Main,[50] performed some delicate experiments on the aging of hardened steels and showed that when martensitic carbon steels age at room temperature there

[44] *Ferrum*, January, 1913.

[45] *Science Reports*, Tohoku Imperial University, Vol. 10, No. 6, pages 453-70.

[46] Ibid, 1925, Vol. 14, No. 2, pages 165-172.

[47] Report No. 42 of the Tool Steel Committee of the Verein Deutscher Eisenhüttenleute, 1923.

[48] TRANSACTIONS, American Society for Steel Treating, 1925, Vol. 7, pages 34-53.

[49] Bulletin, American Institute of Mining and Metallurgical Engineers, 1919, No. 153, page 2389.

[50] *Proceedings*, Royal Society (London), 1918, Vol. 95, page 120.

is a contraction of volume (about 0.0848 per cent by volume) which is accompanied by an evolution of heat that reaches a maximum in from nine to ten days after the water quenching from above the upper critical point. In the case of a carbon steel quenched from above the upper critical, they reported an evolution of heat during aging at room temperature of 404 small calories per gram.

From the fact that the formation of martensite in liquid air did not use up all of the austenite in spite of the vigorous reaction, Hanemann and Schrader[51] concluded that the martensite in the "Fer de Lance" structure as well as the austenite were phases in the metastable equilibrium of the iron-carbon system whose equilibrium could be represented by a diagram. They state that if steel containing 0.05-0.2 per cent carbon is quenched rapidly it will be found to contain ferrite needles (alpha iron) as well as martensite needles which can be distinguished by the difference in color. Their observations led them to believe that martensite was composed of two previously unknown phases of the system which differ from alpha and gamma, so they designated these new phases as epsilon and eta.

They proposed the following diagram, Fig. A, built up—on evidence obtained from the treatment of 5-10 gram steel samples between 2-4 millimeters in thickness. They designated this diagram as the martensite system or metastable system II (the iron-cementite was called the metastable system I). The assumptions involved in this diagram required that there should be a critical on quenching pure iron at about 1270 degrees Fahr. (685 degrees Cent.). By delicate measurements such a thermal effect was found in Krupp iron (0.07 per cent carbon) at about 1270 degrees Fahr. (685 degrees Cent.). They believe that the gamma-alpha change does not take place at this point because the difference in temperature between 1650 degrees Fahr. (900 degrees Cent.) and 1270 degrees Fahr (685 degrees Cent.) is too large to be explained as a simple supercooling effect. They state that the "critical point at T could therefore be called the Ar″ transformation of pure iron."

The concentration of carbon has been assumed to be 0.10 per cent at U, 0.89 per cent at V and 1.40 per cent at point W. The

[51]TRANSACTIONS, American Society for Steel Treating, 1926, Vol. 9, pages 169-233.

authors state that if the rate of quenching for steels of less than 1.40 per cent carbon is fast enough to eliminate the Ar′ transformation, epsilon will separate from the gamma at temperatures between 1270 degrees Fahr. (685 degrees Cent.) and 662 degrees Fahr. (350 degrees Cent.) along the line TW. At 662 degrees Fahr. (350 degrees Cent.), line UW, epsilon reacts with gamma

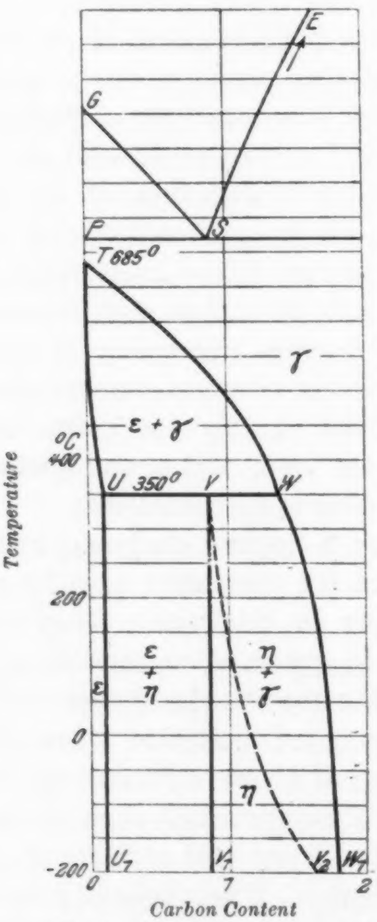


Fig. A—Iron-Carbon Diagram Showing the Lines of the Metastable Martensite System.

to form either epsilon + eta or eta + gamma depending upon whether the carbon is less or greater than 0.89 per cent. On quenching a steel of 0.89 per cent carbon, epsilon of 0.10 per cent carbon reacts with gamma of 1.40 per cent carbon to form the new phase eta of 0.89 per cent carbon at a temperature of 662 degrees Fahr. (350 degrees Cent.). If the carbon is between 1.40 per cent and about 1.7 per cent the peritectoid

reaction mentioned above will not take place and eta (martensite) will separate directly from gamma.

3. EFFECT OF TEMPERING ON AUSTENITIC DECOMPOSITION.—Mauer[52] stated that on tempering a mixture of austenite and martensite between 302 and 482 degrees Fahr. (150 and 250 degrees Cent.) the martensite began to transform first, but this transformation took place slower than that of the austenite. In his steels, which contained 0.06 and 0.09 per cent manganese, he found that the austenite transformed into troostite.

Hanemann[53] concluded that the carbon content of the "martensite hooks" was less than that of the mother austenite. This was illustrated with 0.2, 0.44, 0.86 and 1.30 per cent carbon steels which were quenched from 2012 degrees Fahr. (1100 degrees Cent.) in water and tempered at 1202 degrees Fahr. (650 degrees Cent.) for ten minutes. After the tempering treatment he claimed that there were fewer spheres of carbide in the areas formerly occupied by the martensite. He also agreed with Mauer in that martensite decomposes much more easily than austenite on tempering. The austenite started to change to troostite at 500-536 degrees Fahr. (260-280 degrees Cent.) at the already decomposed needles which acted as inoculation centers and then proceeded from the grain boundaries inward.

Rawdon and Epstein[54] quenched six different carbon steels ranging in carbon content from 0.07-1.12 per cent, from temperatures varying from 1382-2282 degrees Fahr. (750-1250 degrees Cent.), and tempered them for different lengths of time at temperatures between 212-1220 degrees Fahr (100-650 degrees Cent.) From this work they stated, confirming Hanemann, that when martensite plates are tempered they are found to be distinctly lower in carbon than the filling matter between the plates. Below 482 degrees Fahr. (250 degrees Cent.) the structural changes were slight, but at approximately 482 degrees Fahr. (250 degrees Cent.) martensite and austenite if present undergo a transformation and the steel assumes a granular structural appearance and reacts vigorously towards dilute acid etching. None of these tempered specimens showed a scleroscope hardness after tempering

[52] *Revue de Metallurgie Memoirs*, 1908, pages 715-750.

[53] *Stahl und Eisen*, 1912, Vol. 32, page 1397; *International Zeitung Metallurgie*, 1913, 3, pages 127-141.

[54] *Scientific Paper*, U. S. Bureau of Standards, No. 452, 1922.

which was greater than the initial hardness produced by quenching.

Scott and Movius[55] stated that the beginning, maximum, and end of the Ac_t point for a quenched 0.95 per cent carbon steel are 310 degrees Fahr. (155 degrees Cent.), 482 degrees Fahr. (250 degrees Cent.), and 500 degrees Fahr. (260 degrees Cent.) respectively and that this point is markedly raised by increasing the rate of heating. The Ac_t point is understood to mean the thermal effect found in tempering quenched steel and is usually at about 392 degrees Fahr. (200 degrees Cent.) for carbon steels.

Scott[56] determined the density, scleroscope and Brinell hardness values for a high tungsten (17.8 per cent tungsten) high speed steel quenched from temperatures of 1652 degrees Fahr. (900 degrees Cent.), 1940 degrees Fahr. (1060 degrees Cent.), 2228 degrees Fahr. (1220 degrees Cent.) and 2372 degrees Fahr. (1300 degrees Cent.) and tempered cumulatively at intervals of 200 degrees Cent. for 15 minutes. The densities of the pieces quenched from above 1652 degrees Fahr. increased to a maximum between 392 degrees Fahr. (200 degrees Cent.) and 752 degrees Fahr. (400 degrees Cent.) but the specimens quenched at 2228 degrees Fahr. and 2372 degrees Fahr. showed a pronounced decrease on the 1112 degree Fahr. (600 degrees Cent.) tempering treatment. The scleroscope and Brinell hardnesses decreased at approximately 392 degrees Fahr. (200 degrees Cent.) and then rapidly increased to a maximum at about 1112 degrees Fahr. Above 1112 degrees Fahr. the hardness decreased rapidly which was probably due to the coagulation of the carbide. He stated that "the microscopic evidence is positive and confirmatory of the physical, namely that the constituent accompanying the appearance of secondary hardness is martensite." This would mean a transformation from austenite to martensite on tempering.

Bain and Jeffries[57] state that if a quenched high speed steel is tempered the austenite transforms into martensite (between 850-1100 degrees Fahr. (454-593 degrees Cent.) with expansion on and increase in hardness. "At this temperature the iron-tungsten-carbide can form and does form in critical dispersion." As the temperature is raised above 1100 degrees Fahr. (593 de-

[55] *Scientific Paper*, U. S. Bureau of Standards, No. 396, 1920.

[56] TRANSACTIONS, American Society for Steel Treating, 1921, Vol. 1, pages 511-526.

[57] *Iron Age*, 1923, Vol. 112, page 805

grees Cent.) grain growth of ferrite and particle growth of the iron-tungsten carbide produce rapid softening similar to the corresponding process in carbon steel. They also claim that the reason for the retention up to red heat of carbide particles of critical size is caused by the great stability of the tungsten atom which, because of its large size, prevents its diffusion in the ferrite space lattice until a temperature corresponding to a red heat or above is reached.

Some curves showing the effect of length changes on tempering high speed steel were published by French, Strauss and Digges[58] on a steel containing 0.56 per cent carbon, 2.21 per cent chromium, 13.80 per cent tungsten and 0.98 per cent vanadium hardened from 2300 degrees Fahr. (1259 degrees Cent.) in oil and in air blasts. The determinations were made on samples of 1-inch diameter by 4 inches in length which were treated with capped ends. Five sets of determinations showed that when tempered (cumulatively) at intervals of about 200 degrees Fahr. (93 degrees Cent.) a minimum contraction of approximately 0.0002 inch was obtained at 900 degrees Fahr. (482 degrees Cent.) after which the steels rapidly expanded to a tempering temperature of about 1100 degrees Fahr. (593 degrees Cent.). No tests above 1100 degrees Fahr. were reported.

Grossmann and Bain[59] have reported the dimensional changes after tempering a low tungsten steel containing 1.08 per cent carbon, 0.35 per cent manganese, 0.36 per cent silicon, 2.66 per cent tungsten, 0.50 per cent chromium and 0.29 per cent vanadium. Specimens were quenched in oil from 1600, 1700, 1800, 2000 and 2200 degrees Fahr. (871, 927, 982, 1093 and 1204 degrees Cent.). On tempering a maximum contraction was produced at about 260 degrees Fahr. (127 degrees Cent.) which was followed by a maximum expansion at about 500 degrees Fahr. (260 degrees Cent.) and later by a contraction at 1200 degrees Fahr. (649 degrees Cent.) where their experiment ceased. The steel specimens, $\frac{7}{16}$ inch square and about $2\frac{1}{2}$ inches long, quenched from the higher temperatures showed the maximum contraction and the maximum expansion at the temperatures mentioned.

Scott[60] in a recent paper on gage steels containing about 1.10

[58]TRANSACTIONS, American Society for Steel Treating, 1923, Vol. 4, pages 353-397.

[59]TRANSACTIONS, American Society for Steel Treating, 1926, Vol. 9, pages 259-270

[60]Ibid, pages 275-304.

per cent carbon with chromium up to about 1.10 per cent has shown that on tempering the quenched steels similar results were obtained but at different temperatures. He also states that aging at 212 degrees Fahr (100 degrees Cent.) for one hour produces a contraction which is about the equivalent of natural aging for six months. The first maximum contraction on tempering was obtained after one hour at a temperature between 302 and 392 degrees Fahr. (150 and 200 degrees Cent.) while a maximum in the expansion occurs at about 500 degrees Fahr. (260 degrees Cent.). The steels then continue to contract on higher tempering until they reach the value of the annealed steel. He showed that with a higher quenching temperature or with an interrupted oil quench, i. e., by allowing the piece to cool through the hardening range Ar″ in air, the initial contraction (increase in density) would be lower and the expansion at 500 degrees Fahr. (260 degrees Cent.) higher. He also stated that the "apparent cause of this phenomenon (more austenite being retained by oil quenching) is the development of pressure sufficient to retard the transformation at an earlier stage with slow cooling than with fast because of the shrinkage of the martensite matrix produced by transient tempering on slow cooling through Ar″."

Maurer[60a] and one of the authors[61] have shown that when carbon steels, 0.70-1.18 per cent carbon, are tempered there is a rapid falling off of B_{rem} beginning at about 100 degrees Cent with a break in the curve at about 260 degrees Cent., and the remanent induction increases to a maximum at about 500 degrees Cent. and then continues to decrease at a slower rate. These results are in agreement with the work on density and volume changes previously mentioned and indicate that the fall of B_{rem} on tempering is caused by the tempering of martensite while the rise is due to the alpha-iron produced when austenite tempers. In a general way the relation of the coercive force to tempering temperature is similar to the above.

Heindlhofer and Wright[62] found that in the tempering of quenched low chromium ball bearing steel there are two transformations. The first is a transformation from the light to the

[60a]*Revue de Metallurgie Memoirs*, 5, 1908, pages 715-750.

[61]TRANSACTIONS, American Society for Steel Treating, 1924, Vol. 5, pages 27-65.

[62]TRANSACTIONS, American Society for Steel Treating, 1925, Vol. 7, pages 34-53.

dense and is shown by microscopic and X-ray evidence (ionization method) to be a breakdown of martensite. This transformation proceeds over a wide range while the second transformation is confined to the short tempering range between 392-500 degrees Fahr. (200-260 degrees Cent.) and is a change from the dense to the light. The authors state that this transformation is due to the retained austenite breaking down to martensite. In the discussion of the above paper, Styri illustrated with good dilatation curves that two points were always obtained on tempering ball steels of the low chromium type. He stated that the first point is the martensite breakdown (contraction) and the second, which is a discontinuity in the expansion curve, is a positive proof of the presence of gamma iron.

Edlund[63] determined the resistances of eight carbon steels between 0.21 and 1.57 per cent carbon by the fall of potential method at various tempering temperatures (intervals of 10 degrees Cent.) and stated that martensite is transformed into troostite at 212-392 degrees Fahr. (100-200 degrees Cent.) but that the reaction is most marked at 230 degrees Fahr. (110 degrees Cent.). Austenite is decomposed at about 500 degrees Fahr. (260 degrees Cent.), and at 518 degrees Fahr. (270 degrees Cent.) the microstructure of the high carbon steel was wholly troostitic. He showed that even low carbon steels have considerable austenite when quenched from ordinary quenching temperatures. His volume determinations made with a pycnometer showed that when martensite is tempered at about 212 degrees Fahr. (100 degrees Cent.) there is a considerable decrease in specific volume and that when the austenite is tempered there is a large increase in the specific volume.

Bain[64] made up some carbon-chromium steels containing between 1.70 and 2.22 per cent carbon and chromium 6.09-15.65 per cent. On quenching from a high temperature 2100 degrees Fahr. (1149 degrees Cent.) these steels were rendered quite soft and almost entirely austenitic. He stated that on tempering at 900-1100 degrees Fahr. (482-593 degrees Cent.) the steels were martensitized and developed a hardness which was nearly equal to what could be developed by quenching from a lower tempera-

[63]*Journal*, Iron and Steel Institute, 1923, Vol. 111, No. 1, pages 305-14.

[64]TRANSACTIONS, American Society for Steel Treating, 1924, Vol. 5, pages 89-101.

ture. However, Bain mentioned that none of the tempered specimens showed the familiar characteristic martensitic structure but had a structure that strongly resembled troostite. In a later paper Bain[65] stated that the cause of the easier retention of austenite in alloy steels was the stronger atomic bonding between unlike atoms which is necessary for any solid solution and that no further explanation was required for the two classes of alloying elements. The following tabulated data show the range of austenitic decomposition as given by Bain.

	Composition				Range of Decomposition	
Type of Steel	C	Mn	Cr	W	°F.	°C
Carbon	1.10	0.20	....	....	375- 480	190-250
Tungsten Die	1.40	....	0.50	4.0	400- 535	205-280
Tungsten Die	2.00	1.30	1.40	1.0	575- 750	300-400
Oil Hardening	0.90	1.70	....	....	400- 550	205-287
Oil Hardening	0.90	1.20	1.00	....	400- 515	205-270
Chrome Magnet	0.85	0.40	2.60	....	400- 500	205-260
High chrome	1.80	0.35	6.00	....	575-1000	300-535
High chrome	2.20	0.35	10.00	....	840-1000	448-535
High Speed	0.70	....	0.40	18.0	1000-1200	538-650
Hadfields	1.20	12.00	....	....	775-1150	413-620

He stated that "whether or not the product of the change of preserved austenite is martensite depends on this matter of grain growth both in alpha iron and in the carbide. If the carbide precipitation precedes the allotropic change as it usually appears to do, then the product is very much like troostite."

Both Matsushita[66] and Honda[67] claim that in carbon steels there are two kinds of martensite which they call alpha and beta. Alpha martensite tempers at about 356 degrees Fahr. (180 degrees Cent.) and is more easily etched, while beta tempers at about 626 degrees Fahr. (330 degrees Cent.). According to Matsushita[66] the beta martensite is formed on quenching when the Ar″ point occurs between 572-752 degrees Fahr. (300-400 degrees Cent.) but if the Ar″ occurs below 572 degrees Fahr. (300 degrees Cent.) both alpha and beta martensite form.

On tempering high speed steel at 900 degrees Fahr. (482 degrees Cent.) which had previously been quenched from a high heat, Grossmann[68] found that it was actually softer than when tempered at 1100 degrees Fahr. (593 degrees Cent.). He ex-

[65]TRANSACTIONS, American Society for Steel Treating, 1925, Vol. 8, pages 14-22.

[66]*Scientific Reports*, Tohoku Imperial University, 1918, 7, page 43; 1923, 12, pages 1-25.

[67]Ibid, 1925, 14, pages 165-72.

[68]TRANSACTIONS, American Society for Steel Treating, 1922, 2, pages 691-5.

plained this phenomenon on the basis of Honda's two kinds of martensite.

4. Effect of Stress on Austenitic Decomposition During Quenching.—Various theories which considered hardening to be caused by the strain set up in quenching have been advanced by the following well-known scientists: André Le Chatelier, Charpy and Grenet, McCance, and Carpenter and Edwards.

In 1908 Benedicks[69] stated that austenite was never formed near the surface even if the specimens were heated in graphite and quenched so as not to oxidize the surface. He also stated that in liquid air, the transformation of austenite to martensite could not go on beyond a certain limit where the increase in pressure due to the martensite (large volume) would put a stop to further transformation of the austenite on account of the increase in pressure. He heated a 1.99 per cent carbon steel embedded in graphite to above the melting point of pig iron (about 2084 degrees Fahr. or 1140 degrees Cent.). He then poured the pig iron on the specimen and quenched the whole in water. On examination of the edge structure he found that it consisted almost completely of austenite and explained the experiment on the theory that the pig iron in freezing exerted a pressure on the austenite and thereby retained it at room temperature with only a small amount of martensite. He also reported that if the outer edge of a quenched piece was ground off so as to relieve the stress, the austenite would decompose to a martensite. This martensite was noted in characteristic triangular formations several hours later without even etching the specimen.

Wille[70] determined the stresses produced in the quenching of large forgings 9½ inches in diameter containing 0.41 per cent carbon and 0.55 per cent manganese. After quenching the sections, a series of three rings were cut from each section and accurately measured before they were detached, so that the fiber stress at different diameters could be calculated. The depths of the rings from the surface were ½ inch, 1⅝ inches, and 2¾ inches. All of these rings expanded showing that they were under compression. The first ring had a compression in pounds per square inch of 42,600, the second 29,500 and the third 16,500,

[69]*Journal*, Iron and Steel Institute, 1908, No. 2, pages 217-256.

[70]*Proceedings*, American Society for Testing Materials, 1915, Vol. 15, No. 2, pages 27-38.

when the forging had been quenched in water at 70 degrees Fahr. (21 degrees Cent.). When quenched in oil the first ring calculated 42,300 pound per square inch, the second 16,800 and the third only 4,500. In conclusion he stated that the internal stress developed in water quenching was of much greater magnitude than when oil quenching was used.

Tafel[71] stated that if a body of steel were heated to a high temperature the stresses would be low but if the body were quenched the core would have a greater unit volume than the colder shell and be under compression while the case would be under tension. As the interior cools to the same temperature as the shell it will shrink but since the shell has assumed a greater volume than normal, the stress gradient will reverse leaving the shell in compression and the core in tension.

Jasper[72] arrived at the same conclusions from his researches on 0.49, 0.90, and 0.92 per cent carbon steels.

Scott[73] has shown by the aid of Heyn's method for measuring axial stress by grinding off successive layers on a cylindrical rod, that the surface stress of a water quenched deep hardening steel in bars of 1-inch diameter containing about 1.0 per cent carbon, 0.03 per cent manganese, 0.35 per cent silicon and 1.4 per cent chromium, remains under slight compression at room temperature (approximately 30,000 pounds per square inch). A surface hardening steel containing 1.1 per cent carbon, 0.03 per cent manganese, 0.2 per cent silicon and 0.3 per cent chromium, was found to harden only to a depth of about ⅛ inch but showed a greater compressive stress at the surface (about 110,000 pounds per square inch). He explained the high compression on the surface hardening steel as due to the fact that the martensitic shell had a greater specific volume than the soft core. These tests confirm the work of Tafel and Wille and show that after hardening there is a reversal of stress resulting in case compression and core tension.

French, Strauss and Digges[74] believe that pressure plays a large part in the efficiency of a high speed cutting tool and state:

[71] *Stahl und Eisen*, 1921, Vol. 41, page 132.

[72] *Engineering*, 1924, Vol. 118, page 343.

[73] *Scientific Paper*, U. S. Bureau of Standards, No. 513, 1925.

[74] TRANSACTIONS, American Society for Steel Treating, 1923, Vol. 4, pages 353-397.

"Tools which will cut under frictional temperatures of 1400 degrees Fahr. (760 degrees Cent.) would be entirely ruined if first tempered at this temperature. It is therefore conceivable that the pressure tends to retard the reaction which would take place at a given temperature and so tend to prevent tempering or at least make it take place so slowly that the tools will cut for a definite length of time at such high heats before failure occurs."

5.—Effect of Cold Deformation on the Austenitic Decomposition. Hall and Hanks[75] reported that cold working the surface of an austenitic "Hadfield manganese steel" containing 11.0 per cent manganese and 1.0-1.4 per cent carbon increased the Brinell hardness from about 190 to 450. They stated that under a sand blast (light abrasion) the manganese steel wore as fast as an ordinary 0.25 per cent carbon steel but stood up better than the usual hardened or tempered steels under heavy pressures. It is well known that it is practically impossible to cut this steel with a hack saw even though the Brinell number is low. It is believed by some that the abrasion produced in sawing causes the gamma to alpha inversion to take place. The gamma to alpha transformation at the slip lines in manganese steels was discussed by Howe in 1915.[76]

Whiteley[77] claimed to have made "zig-zag martensite" from a high carbon austenite at room temperature by a "high blow." He later tempered the needles at 392 degrees Fahr. (200 degrees Cent.) and formed troostite.

Bain[78] austenitized a steel containing 2.2 per cent carbon and 10 per cent chromium by quenching from a temperature of 2102 degrees Fahr. (1150 degrees Cent.) and obtained a Rockwell "C" hardness of about 40. After reducing the section by hammering at room temperature (15 per cent reduction), a hardness of 58-61 was obtained and the specimen was found to be quite magnetic. An X-ray crystallogram of this cold-worked steel showed both alpha and gamma iron lattices while the original austenitized steel showed only a gamma lattice. In other words,

[75] *Proceedings*, American Society for Testing Materials, 1924, Vol. 24, page 626.

[76] *Transactions*, American Institute of Mining and Metallurgical Engineers, 1915, Vol. 51, page 886.

[77] *Journal*, Iron and Steel Institute, 1925, Vol. 1, pages 315-338.

[78] Transactions, American Society for Steel Treating, 1925, Vol. 8, pages 14-22.

he showed that cold working greatly aided the inversion of gamma to alpha but did not mention that a martensitic structure was developed.

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SELECTING MATERIAL FOR SERVICE

By F. E. Schmitt

Abstract

Testing to determine the fitness of material has grown with the number and variety of technical materials, but it has lagged, and is hardly adequate to the needs of the present and future. Certain specific instances of modern service requirements, as well as the practice of duplicate specifying, support this statement. The primary trouble is that the testing engineer usually measures conventionalized properties, whose correlation with daily service demands is largely unknown. Therefore, we should develop tests of suitability for desired service, in place of or to supplement the present conventionalized tests. In such development of suitability tests, users of materials have an excellent opportunity to assist.

WITHIN a few decades, about the same period that saw the development of modern steel, the art of testing constructional materials evolved. Beginning with crude items of experimental work it has reached a high stage of development. Its field is to determine the fitness of material for a particular service, and accordingly it has a vitally important place in modern engineering. We cannot calculate strength or safely design for high efficiency unless we make sure that the expected strength of material is actually realized. It is no longer economically possible to provide the large margins of former times for random variation from the assumed standard of quality.

The demands upon testing have grown with the extension of old materials to new uses and the production of new materials. A variety of aids has been called into service to meet these demands. All the resources of the mechanical and chemical laboratory were drafted, new instruments and methods of study were developed, and the assistance of micrography was brought to bear on the new problems. By these means the tester, who later became the testing engineer, kept abreast of the ever greater demands. Today a large part of the production, purchase and use

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of constructional materials is dependent upon his skill, and the testing of materials has become an essential component of the modern production system.

Advance of the technical art is going on, however, at an increasing rate. In recent years the variety of materials and the varied character of their utilization has grown remarkably, far more than we realize. Steel, for example, has increased vastly in kinds and grades, and in the range of their commercial utilization. Corresponding advance in the testing art is essential, to keep pace with these increasing requirements. Therefore, though in historical perspective the art appears well developed, we may properly inquire whether it is adequate to the needs of today and of the immediate future. Is the art efficient and satisfactory?

An offhand answer is bound to be affirmative. But if we reflect on the nature of current and coming demands, and the ability of the art to meet them, doubts will appear. Consider, for example, some happenings in the field of materials and tests.

Mechanical progress of the present century has brought forward high-speed machines, with high efficiency use of material—which means high stress. Among these are steam turbines, submarine and airplane engines. Failures occurred that were not readily explained on the basis of ordinary comparisons of stress and strength. It seemed that the endurance of the material under a great number of stress repetitions was involved. If so, it would follow that the selection and current control of material for the critical members should depend on regular endurance testing. But this field has been little explored. The required tests are costly, delicate and tedious, and testing engineers had never gone into the question of devising a short-time or commercially usable test of endurance. In a high-pressure attempt to make up for the previous neglect there is now in progress a series of investigations of the endurance of metals under oft-repeated stress, which aims among other things to discover laws correlating endurance with simpler test properties so that we may be able to dispense with endurance testing. In this case we find that the testing art was caught napping by advancing practice.

In another field the picture is a little different. For more than a quarter century systematic study has been given to methods of appraising the service value of paints for corrodible metals.

Yet the results to date are practically zero. Years of large-scale experimenting have been devoted to exposure tests, unfortunately devised with a view not to developing a short-time substitute test, but to comparing certain paint mixtures directly, and therefore of limited value. Laboratory tests have been studied more or less, including tests of the elasticity and perviousness of paint films, but to no particular effect. On the whole we are not a particle farther ahead in paint testing than in 1900. Progress is in sight, for strong efforts are being centered on formulating an accelerated exposure test suitable for standardization and yet simulating practical service conditions. For the present, however, in the field of paint the matter of estimating service quality by test is in a backward condition.

A third case: Three or four years ago the alloy duralumin was applied on a large scale to a very important service, construction of the framework of the dirigible airship "Shenandoah." It was known that similar material was liable to a peculiar disease, embrittlement by inter-crystalline cracking probably promoted by corrosion. With a truly efficient testing art it should have been possible to question the material for the "Shenandoah" before using it, and to verify its resistance to this disease. The testing art failed to meet this requirement, and two years after the ship was built its framework proved to be attacked rather severely by intercrystalline cracking.

So the art appears to have serious shortcomings. We might discuss other instances, involving various unpleasant surprises, some serious and some merely annoying. They would doubtless include the troubles incident upon the discovery of the so-called snowflakes in ordnance steel, and the inability of both steelmakers and testing engineers to deal with the problem promptly. But instead we may consider a more general indictment of materials testing. This rests on the practice of duplicate specifying.

The practice is widespread, almost universal, in our specifications of constructional materials. We describe a desired material both by chemical composition and by mechanical test properties, though only the mechanical properties will count in the service to be performed. Often we specify in addition also the process of manufacture. Evidently we do not trust the testing engineer's ability to select and control material quality. This

duplicate specifying is not new; it has been practiced ever since modern production and purchase of materials began, always with the hope that improvement of testing processes would in time make it unnecessary. The hope has not been realized, rather the contrary. Duplicate specifying has if anything increased, and today is more firmly embedded in specifications than ever. The art of testing has not improved, it seems, but has lagged behind the arts of production.

One of the main causes of the failure of the testing art to meet in full our present-day needs is the fact that it has been made to serve the function of testing for quality rather than testing for service. We have been testing materials for supposed excellence, as defined in terms of certain limited properties accepted as indicators of value. We have left correlation of material and service to the user, to the designing and constructing engineer, although the latter himself must rest his judgment on the test properties reported by the tester, taken in connection with experience.

Present day needs call for development in the other direction; they demand direct service testing; suitability testing. From this we may obtain results expressed directly in terms of the specific resistances or excellences which the material is required to display in the contemplated service. It is not essential to attempt to analyze what these excellences or resistances may be, an endeavor which too often proves abortive. In particular cases we may, as a secondary stage of the test work, resolve the service resistance of the material into more elementary or unit qualities —for example, to determine whether the degree of suitability of a given steel for guide bushings is measured by its hardness, or its surface texture, or its freedom from inclusions, or perhaps its total resilience. But this is not an inherent part of the method, and requires to be used cautiously and within narrow limits. The service test itself remains the primary reference datum.

To appreciate more fully how thoroughly we are committed to quality tests let us survey the current test methods for iron and steel.

As general methods, we have a tensile test, which measures breaking strength, elastic limit, and ductility, and sometimes a few related or derived quantities; we have bending tests, applied

to certain grades of steel as a measure of ultimate deformability or perhaps plasticity, and, related to them, a few other special tests of deformability such as the drifting test for boiler and structural steel; we have so-called hardness tests of several kinds, as the Brinell ball test; impact bending to judge of toughness (or its opposite, brittleness) and to reveal defects; examination of microstructure; segregation measurements, both by direct chemical analysis of samples taken from different points and by sulphur printing; and acid etching to determine localized corrodibility as an indication of probable defects or sharply localized structural differences.

Perhaps this list should be increased by the mention of measurement of internal strains, though direct mechanical testing for such strains has been done only in occasional instances for purposes of special study. The practice in steel testing of making parallel tests for the several properties named, in the initial state and after annealing, is also in part a test for initial strains. Repetition of the tests after other heat treatments is used variously to throw light either on the adaptability of the material to improvement by heat treatment, or on the absence or presence of any measurable hardening power in cases where this is objectionable, as notably in rivet steel.

In a separate group from these we have various special tests, some of which are used only rarely while others are still in the process of evolution. These include endurance and torsional tests on the one hand, and magnetic tests and X-ray examination, on the other.

It will be seen that all the tests named are conventionalized quality tests, whose meaning depends on what we are able or willing to read out of them for a particular group of service conditions. Occasionally, it is true, a single test of the list may represent quite accurately the predominant service demand, and then of course it is in fact a suitability test. Thus, selection and control of steel for transformer cores depends mainly on the permeability and hysteresis of the material and to freedom from aging, while with respect to mechanical properties the requirements are so moderate that mechanical tests are secondary. Again, steel intended for tension bars may be fully tested for suitability by a tension test. But in modern work these single-property

services are infrequent; the great majority of services depend either upon an intricate composite of unit qualities or upon qualities that we are unable to analyze and correlate with the simple test properties.

Balls and ballraces must meet requirements not directly expressible in terms of our ordinary tests. Rock-drill steels, crusher jaws and linings, pistons, cylinder shells and the like present the same situation. In many mechanical parts we are critically concerned with surface wear, yet our list includes no tests for resistance to abrasion, nor have we yet been able to determine whether such resistance involves a single characteristic property or is a composite of several different resistances. Surprisingly many uses of iron and steel, indeed, are obviously not susceptible to analysis into elementary test properties; and it may safely be asserted that on careful consideration nearly all uses will be found to be of this kind. Service which depends upon strength alone, or hardness alone, is the exception.

It is interesting to remark that in its origin testing undoubtedly consisted altogether of suitability tests. The very meaning of the word testing implied trying and proving, that is, putting to the test of service. If the old time smith when he had forged a sword did not prove his product by cutting down his neighbor, yet he surely verified its temper and toughness and its freedom from flaws by bending it as severely as it would ever be bent in battle, and he made certain that it could take and hold a keen edge and a high polish. And when, much later, in the young days of modern structural engineering, wrought iron for chains and tie rods was proved for strength in the early testing machines, it was being tried out plainly for service suitability.

But the complexity of even fairly simple service, and the difficulty of reproducing it by a short-time severe trial, must have been evident almost from the first. The natural result was simplification and formalization of test procedure, the substitution of artificial for real service. Probably two rather different ideas were concerned here: First, upon analysis of the service, selecting what seemed to be the controlling property or properties used in that service, and, second, upon study of the material, picking certain simple test properties as the defining quality characteristics of the material and making them the criteria for its accept-

ance and grading. At all events, both these ideas may be discerned in the subsequent application of elementary quality tests, and both have exercised a limiting or misleading influence on the development of materials and the adaptation of material to service.

Throughout the development of testing the greatest part of the activity of the art has been centered on a small number of tests of simple or elementary properties, such as those already mentioned. Used as criteria of quality and as points of departure for deciding upon suitability of material for a given service and even the dimensioning of mechanical members and details, these tests have been regarded with such complete confidence in the correctness of the procedure that for our major material, at least, service suitability tests came to be practically forgotten.

There were some interruptions in this evolution. Brittleness tests, for example, have been under development and discussion for decades, and even yet have not reached the point where we can class them as satisfactory either in consistency and accuracy or in the interpretation put upon them, although the sudden breaking of treated steel has always been an outstanding danger and annoyance in its use. The plain reason is that toughness is one of the practical qualities which persists in eluding our attempts at analyzing it into ready-made testing-machine equivalents.

Perhaps for similar reasons certain suitability tests were retained in specifications for structural steel and iron for many years. It was customary to specify a tensile test, a cold-bending and quenched-bending test, malleability or flattening tests, cold and hot, a drifting test in which a hole punched near the edge of a plate was enlarged by a tapered drift pin, and for rivets an upsetting and a head flattening test—all of them direct duplications of service conditions. These tests have been abandoned, however, and generally the course of test development has been strong and steady along the line of conventionalized simple tests other than service tests. In the full development of this process, as we have it today, the quality of a material is defined by certain agreed-upon requirements, which are assumed to express the essentials of what the material is able to do and what it is or should be called upon to do. And this assumption is, on the whole, arbitrary and of weak justification.

It would be a mistake not to recognize the value of conventionalized tests. To a large extent they are indispensable. Cast iron affords an example. The material is obviously difficult to put to trial for the specific service of a particular piece—for instance, a water pipe, a machine frame, a pulley. Practical experience, however, long ago taught us that for certain of these uses a soft iron with a high deflection in cross-bending is excellent, while for certain other uses a mixture of high strength and close grain may be preferable even though its bending deflection be rather low. Practical conclusions of this kind naturally lead to a cross-bending test, and it is a test entitled to a great deal of respect as an index of cast iron quality, though obviously it is a conventionalized test.

In fact, quite generally, conventionalized tests are excellent tools so long as materials and service requirements remain constant. Accordingly, during the period of relatively few major materials, and these of approximately constant grade and method of production and use, the extensive development of conventionalized quality testing was a most valuable and efficient guide to both the using and producing industries. Present-day conditions are distinctly different, however. Our slowness to assign the numerous high-grade alloy steels to their proper fields of use is chargeable to the sway of old-time quality tests and the absence of direct service testing. If we must wait on the slow conclusions of experience to correlate new materials and services we are failing to utilize the testing art to full advantage, and we are incurring great losses in the process.

Testing serves industry in different ways, and none should be undervalued. It serves among other things to control manufacturing processes, to verify uniformity of product, and to reveal defects in the product. These functions will always be of great importance to industry. But determination of service value and selection for specified service remain after all the controlling objectives of testing. If for the former purposes we may depend upon quality tests of the conventional kind, yet the needs of the other purpose, the primary purpose, should have most careful attention. It is for this purpose that the art needs the fuller development of service testing.

Mere statement of this need is easy. Putting it into prac-

tice is much more difficult; for to reproduce service in the test room is by no means a simple undertaking. Generally, indeed, the tester himself will be imperfectly equipped to grasp the full scope of service demands and to represent them effectively in a test. He requires the co-operation of the user—of the production and operating engineer—in working the problem out. The present remarks are intended to bring this to attention, and to point out the user's share of responsibility for future testing development.

To realize some of the reasons for and the difficulties of service testing, let us take a rather intricate case, which is of unusually widespread concern because of its relation to public safety. This is the problem of good rails for railway track. Ordinary steel rails are made of carbon or carbon-manganese steel, with incidental impurities of which only silicon has particular importance. Its composition is nearly eutectic, and the rail in its manufacture is somewhat hardened by air cooling—an unregulated kind of heat treatment. Specifications define its chemical composition (within rather broad limits), control the rolling temperature by limiting the shrinkage in cooling after the last rolls, require a surface examination for pipe, and specify a drop test, in which a 2,000-ton weight is dropped on a short length of rail laid as a beam over supports 3 to 4 feet apart, the fall of the weight being 12 to 21 feet. This is the whole quality specification. The rail must not break under the first blow, and in any event before breaking it must show 6 per cent elongation in a 1-inch gage length on the tension side of the beam directly under the falling ram.

This test is described in the specifications as one "to determine ductility or toughness as opposed to brittleness." Though rails are actually made, bought and put into the track on the strength of this test, there is only the vaguest kind of knowledge as to its significance in discriminating between good and bad rail for railway track service. Track experience accumulates slowly; it is an outstanding example of the slow rate at which some tests are subject to check by service experience. During the time when a given lot of rails is in the track, both traffic and track conditions change, and practice as to speed of trains, weight of rail, and the like varies; and at the end of the period the

statistics of service obtained from this lot of rails may be exceedingly difficult to interpret to any good effect. In spite of such obstacles, we can say that the drop test is not an infallible detector of unsuitability in rail; it is not without value, but its value is rather undefinable. The test does have some sort of relation to the strength, the toughness, the solidity of the rail, and absence of segregation, but it does not protect fully in respect to any of these and, what is worse, it seems to be practically ineffective against a defect that has proved especially formidable, namely, the interior transverse fissure.

It will be seen, too, that rail testing gives no consideration to wear resistance, which is a factor of obvious importance in rail service, nor to surface hardness as a property enabling the rail to resist the destructive cold rolling of its head by the car wheel. And, indeed, we do not depend on the drop test, though it is the only test applied. We specify the chemical composition, the manufacturing process, and in a small way the thermal treatment. The main function of the test is to supply an approximate control of the brittleness of rail steel of a stated composition, which latter is fixed by judgment based on track experience without regard to test. In other words, in this field tests have been substantially valueless in the selection and improvement of material. And the salient point of the case is that, in consequence, rail specifications have been matters of dispute for many years, and rail quality has been more discussed and more fruitlesssly discussed than almost any phase of material utilization. It may be predicted that no marked improvement in rail quality is likely to be attained until service tests are developed and applied —always excepting the possibility of some chance innovation of revolutionary kind.

The weakness of the system of rail appraisal is our inability to analyze track service and to interpret it in terms of the requisite resisting powers of the rail so as to be able to apply elementary tests of the ordinary laboratory kind. In this respect the case of rail, though possibly a little extreme, is typical, and it is cited here for that reason. Most mechanical elements present almost as complex problems. Because of this situation it is hopeless to look for improvement of practice or guidance in selection of material by our conventionalized laboratory tests of quality. Im-

provement can be brought about only through direct service or suitability testing.

In so far as the argument bears on steel, it may be objected that with the rise of microstructure study the whole aspect of testing has been altered. Micrography has produced such far-reaching results that it is only natural if we look to a time when it will solve in full all questions of quality and suitability. But such hopes appear to be over-sanguine. They overlook the fact that if knowledge of microstructure simplifies the problem of quality in some respects, it complicates it in others. We no longer deal with one material, steel, but with half a dozen or more, the component structure elements. Our knowledge of the properties of the aggregate rests on knowledge of the properties of the components, and this in turn must be derived by inference from the observed behavior of steel grades in which the several components appear thus or thus combined. If our previous problem had to be solved by trial methods, the substitute problem is in effect a group of simultaneous equations involving cementite, ferrite and the other x, y and z's as unknowns, and as the constants of each equation are themselves undetermined the last state is not so definitely better than the first.

We are sure to profit quite as much in the future as in the past from the utilization of micrography and its derivatives. But on the present outlook it must be set down as improbable that it can simplify essentially the problem of suitability determination. Giving all possible credit to the probable contributions of micrography, we will yet need to develop service tests as our prime guides to efficient use of materials.

In summary, to state the case briefly: Our testing hitherto has been directed to measuring a few analytical properties, in the belief that these would represent the full range of service quality. The test of practice shows this belief to be rosily optimistic, yet we have exploited the plan quite fully, and have settled back to doing little more than appraising quality by conventional measuring sticks. This is remotely like the attitude of the period when profound study of the theory of elasticity was believed to be the key to structural design, when we expected to solve all problems of mechanical resistance by calculating the maximum attack on a loaded piece in terms of elementary compres-

sions, tensions, and shears. Our attempt to compound out of tensile, compressive, and shearing strength, ductility, hardness, and impact strength the vast range of service attack and resistance has not been successful.

Practice recognizes this. In selecting and approving materials for specific service and deciding on their essential grade characteristics, practice depends on experience, and only afterward is the art of testing called into the case for routine checking of production. This is neither the best function of the art, nor does it meet the needs of constructors. It serves well so long as material and service both remain constant, but it is of little help when either material or service undergoes change. When increasing weights and speeds of railway traffic call for more resistant rail, our tests and the accumulated records of test values fail to tell us what kind of new rail we need—how hard or strong or ductile it should be. When a new, stronger steel is demanded for high-duty crankshafts, tests do not tell us what grade will be successful; again, we must rely on the verdict of service. Or, if we wish to use a certain kind of rubber fabric for floor surfacing or for belting, the tester does not help us. In short, service suitability is largely or wholly beyond the reach of the testing art, as generally practiced.

Development of suitability tests, in the coming era of testing, has already begun, and in some materials rather actively. Electrical production, dealing from the beginning with new materials under new service, resorted to service tests at the start and has consistently followed the practice. In other materials, in fabrics, composition, brick and tile, lubricating materials and bearing metals, the inadequacy or inapplicability of routine testing-machine procedures also has brought about an increasing trend toward suitability tests. Iron and steel yet lag behind in this development. They must follow in the same course, if the large range of possibilities residing in their valuable properties and the great range of our power to control these properties by alloying and treatment is to be realized fully.

And, finally, in this future development the user of material bears a definite share of responsibility. His co-operation is needed.

STANDARDIZING THE BRINELL HARDNESS TEST

By H. M. German

Abstract

The accuracy of the Brinell hardness test is governed by the accuracy of the applied load, the rate of application of the load and the time the full load is applied. All of the present Brinell machines possess one or more of the following defects; They do not exert an accurate load of 3000 kilograms pressure, but are subject to overloading and underloading, the time and rate of application of the load is not constant, and the time of full load application is not fixed. The accuracy of the readings obtained are dependent upon the design of the machine and the care and skill of the operator.

The paper points out the defects in the different types of machines and describes a new design which will over come the above defects and eliminate the personal factor of the operator, thereby standardizing the Brinell hardness test.

THE Brinell test is a measure of hardness by deformation. It is based upon the fact that if a hard and rounded object is pressed against a softer material having a flat surface and held in a rigid position, the hard object will deform or indent the softer material. The amount of deformation will vary according to—

1. The hardness of the hard object
2. The hardness of the softer material
3. The applied pressure
4. The rate of application of pressure
5. The time the full pressure is applied.

The hardness of the hard object.

The hard object is a hardened steel ball ground to a diameter of 10 millimeters and sufficiently hard that it will not deform permanently in tests. If the ball deforms under load, it will flatten at the points of applied pressure and produce a shallow impression, which will give an inaccurate reading. The harder the ball, when tested with a Rockwell cone, the less it will deform under pressure. Rockwell cone tests on several makes of balls show readings of 64 to 67.

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Brinell balls are usually made from steel containing 1.00 to 1.20 per cent carbon and 0.50 to 1.25 per cent chromium. They are given a double treatment in hardening. The first treatment consists of heating to a temperature approximately one hundred degrees Fahr. above the critical point and quenching in either oil or hot water for the purpose of removing fabricating strains and refining the grain structure. In the second treatment they are heated to just above the critical point and quenched in water. The hardened balls are not tempered. An ideal structure for Brinell balls consists of a very fine groundmass of martensite in which are imbedded fine grains of double carbides.

A. Hultgren[1] has found that by cold working a hardened and polished steel ball, the surface is hardened to a sufficient depth to enable the ball to withstand considerably greater pressure than ordinary steel balls without appreciable permanent deformation. Balls given the above treatment permit accurate tests on materials up to number 700 Brinell hardness. He also reports, that when testing hard steel, a sharper definition of the impression circle may be obtained by the use of etched balls. This is accomplished by etching, after cleaning with alcohol, in a one per cent solution of nitric acid in alcohol for a period of about three minutes.

The hardness of the softer material

The hardness of the softer material is the hardness of the material to be tested and is therefore variable. The Brinell test has its limitations in that the only articles that can be tested are those that will stand permanent deformation and those that are of sufficient thickness and hardness that the force of penetration will not show a bulge on the opposite side of the test piece. The minimum gage limits for Brinell tests on 1.00 per cent carbon steel at different tempers were shown in a previous paper.[2]

That part of the sample to be tested should present a flat and smooth surface free from scale in order to obtain a sharp definition of the impression circle under the reading glass.

The applied pressure

When testing iron, steel and other comparatively hard mater-

[1]A. Hultgren, "Improvements in the Brinell Test on Hardened Steel, Including a New Method of Producing Hard Steel Balls."—Iron and Steel Institute, Autumn Meeting, September, 1924.

[2]H. M. German, "Testing Steel for Hardness," Transactions, American Society for Steel Treating, Vol. 3, 1923, p. 489.

ials, the standard load is 3000 kilograms but when testing soft materials, like lead and babbitt metal, a load of 1500 kilograms is frequently used. In order to obtain accurate readings it is essential that the load be fixed and not subject to variations. There are different types of Brinell machines which may be classified according to the manner in which the load is applied, namely, hydraulic, weight and levers, and weight and eccentric.

The hydraulic type consists of a small hydraulic press having a downward acting plunger carrying the ball which is pressed into the material to be tested. Pressure to the hydraulic fluid, which is usually oil or glycerine, is applied in different makes of machines by a small compressor or pump actuated by hand, with a lever or wheel, or by power; the wheel being driven either by belt or motor. Different devices are used to regulate the pressure, such as, gages, gage and springs, and gage and check weights.

In the gage regulating machines, pressure is applied until the gage indicates that a load of 3000 kilograms is reached. In one make, two gages are provided, one for routine and one for checking. This method of pressure control is disadvantageous in that there is always danger of underloading and overloading and that pressure gages do not permanently retain their accuracy. Regulating pressure by gage and springs is an improvement over the above method in which the danger of overloading is eliminated. When the pressure reaches a fixed load, a valve controlled by adjustable springs opens so as to maintain the fixed load. The disadvantage of this device is that neither gage nor springs permanently retain their accuracy. The most common method of regulating the pressure is by means of a gage and check weights. In order to check the accuracy of the gage, a piston is provided with a dead weight control which limits the amount of pressure obtainable to that required for the test. As long as the piston floats (forming a small hydraulic accumulator) the desired pressure is maintained. This device has the disadvantage of overloading, as an extra pressure is necessary to overcome inertia in raising the weights, and there is an extra pressure due to the rising and falling motion of the check weights in reaching equilibrium.

Most hydraulic machines have a tendency to leak after they have been in operation some time and the hydraulic fluid becomes stiff and sluggish in cold weather. There are two types of weight

and lever machines; one, in which the load is obtained by weights and compound levers and applied to a plunger containing the ball which is pressed into the piece to be tested, and the other in which the test piece is pushed upward against the ball until it will balance a load obtained by weights and compound levers.

When making a test with the first type, the piece is adjusted snugly against the ball, and then the load is applied by lowering the weights with a hand crank until the weights suspend freely. By this arrangement it is not possible to overload, and the load will always be constant. This type of machine can be equipped to operate the weights by air or water pressure.

Pushing the test piece against the ball is not as accurate as allowing the weights to exert pressure against the ball as overloading is necessary to overcome inertia in lifting the weights, and there is additional pressure due to the swing of the weights.

The weight and eccentric type of Brinell machines, better known as the Johnson ball hardness machine, has found very few users in this country. On rotating a lever attached to an eccentric, the hardened steel ball is forced into the material to be tested. The load is regulated and applied by means of an eccentric together with the attached lever and weight. Should the pressure tend to rise above the predetermined load, there would immediately be an upward movement of the weight. This machine also possesses the disadvantages of overloading to overcome inertia in lifting the weight and swinging of the weight.

A review of different devices for applying pressure shows that only one, the first type of the weight and lever machine will give an accurate and constant pressure.

The rate of aplication of pressure

It is a recognized fact that metals under mechanical work or compression when cold change in hardness and become more resistant to deformation up to the point of rupture. The extent of this change varies not only in different metals but also according to the rate of application of pressure. The rate of application may be sufficiently slow to permit an even distribution of pressure from the ball or it may be rapid enough to have the effect of an impact. If the pressure is applied rapidly, the depression will be greater than if it is applied slowly and gradually. The average difference between a fast and slow application of pressure with a hydraulic

machine operated by hand lever is approximately 0.1 millimeter in diameter for medium hard metals; the softer the metal the greater will be the difference. This difference is greater with the weight and lever type in which the test piece is pushed up against the ball and with the lever and eccentric type of machine in which overloading takes place in order to overcome inertia in raising the weights and the increased pressure due to swinging action of the weights. In not one of the machines described has provision been made to insure either a steady application of pressure or a fixed time for the application of the full load; they being left to the discretion of the operator.

The time the full pressure is applied

Another important factor that influences the depth of indentation is the duration of time that the full load is applied. A short application of pressure will not give consistent readings as it requires time for the full pressure to exert itself in pressing the ball into the test piece and reach an equilibrium. This is clearly shown in the following test:[3]

Period of Application Seconds	Brinell Readings Diameter Millimeters				Average Readings
5	3.125	3.125	3.125	3.1	3.12
10	3.15	3.15	3.15	3.15	3.15
20	3.2	3.15	3.15	3.15	3.16
30	3.175	3.175	3.175	3.175	3.175
45	3.2	3.175	3.175	3.175	3.18
60	3.2	3.175	3.175	3.175	3.18

In this test the maximum reading was obtained in 45 seconds; there being no increase with an additional 15 seconds. In commercial testing, the average duration is 10 seconds, but when more accurate readings are desired 30 seconds will give more consistent results. A standard time should always be used. No provision is made in any of the present existing Brinell machines to automatically fix the time for the application of the full load, it is also optional with the operator.

An improved hardness testing machine—Brinell type

A review of the foregoing discussion discloses that errors in Brinell testing arise from the following causes: First, that the applied load is not constant owing to the design and manipulation

[3]H. M. German, "Testing Steel for Hardness," Transactions, American Society for Steel Treating, Vol. 3, 1923, p. 489.

of the several machines. Second, the rate of application of pressure and the time the full load is applied are not fixed, but are optional with the operator.

The following design of a machine is offered to overcome the above defects.

This is a design of a machine which may be classified under the weights and levers type; the weights being lowered and raised automatically by means of a cam actuated by a constant speed motor. When making a test, the material to be tested is placed on

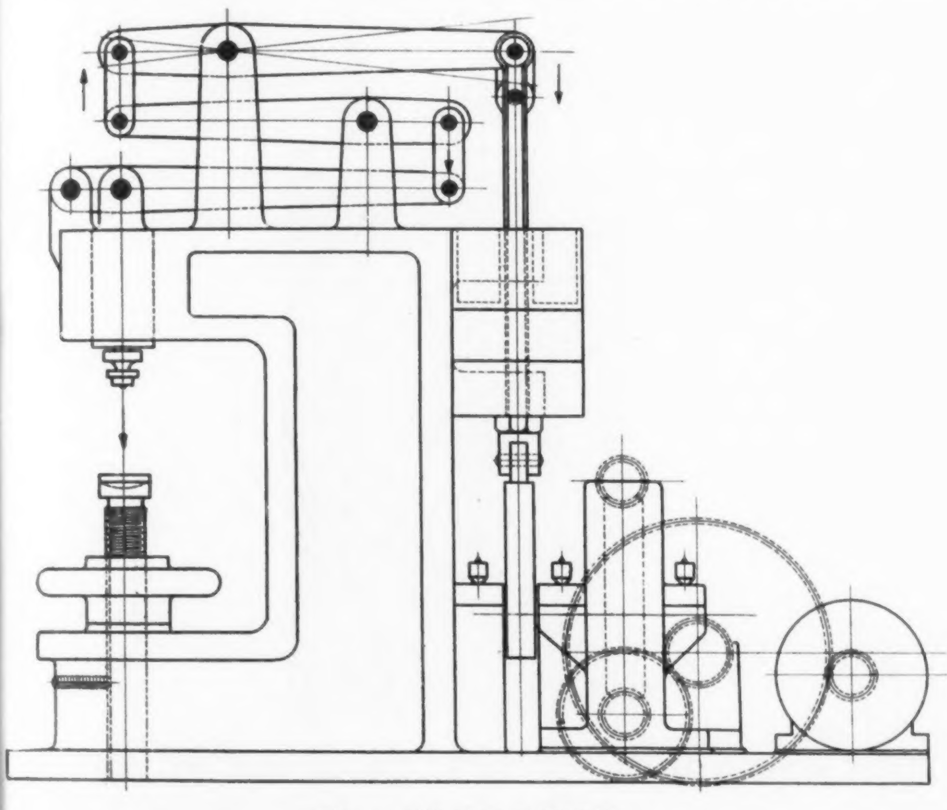


Fig. 1—Side View of Machine.

the anvil and raised snugly against the ball by means of a screw and hand wheel. By pressing an electric switch button, the motor is started and the cam rotates. As the cam revolves, the weights are gradually lowered and pressure is smoothly and gradually applied to the ball. When the cam has revolved approximately 90 degrees, the cam leaves the roller supporting the weights and the weights are free to exert their full load upon the ball. There is no overloading to overcome inertia and there is no swinging or up

and down motion of the weights. From points representing 90 degrees and 270 degrees in the revolution of the cam the full load is applied. The load is constant and the time is fixed. At a point representing 270 degrees in the revolution of the cam, the cam again engages the roller and raises the weights smoothly and gradually. When the cam has revolved nearly 360 degrees, the

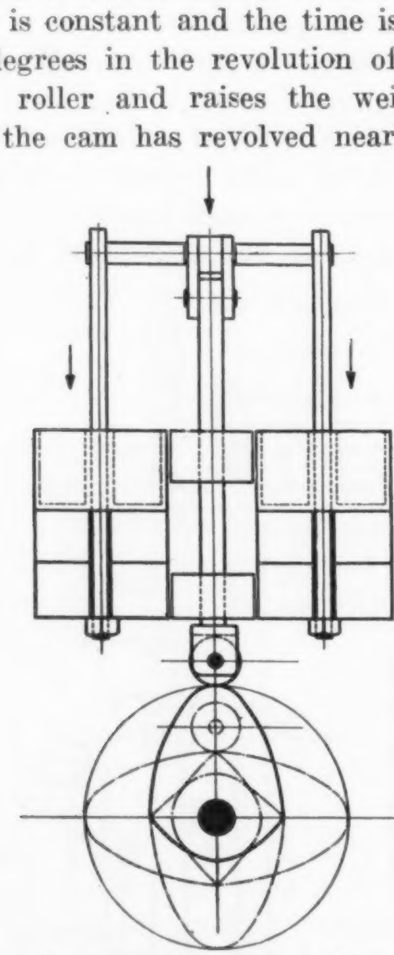


Fig. 2—End View, Showing Cams.

current is automatically shut off so that the cam will make one complete revolution in making the test. If the speed is adjusted to make one revolution of the cam in one minute the cycle would be as follows: 15 seconds for applying the load, 30 seconds for application of the full load, and 15 seconds for the release of the load. By changing the gear ratio and the design of the cam any desired time and rate of application and time for the full application of load can be altered.

The improved Brinell testing machine removes the personal factor and fulfills the following requirements.

1. The rate of pressure application is fixed

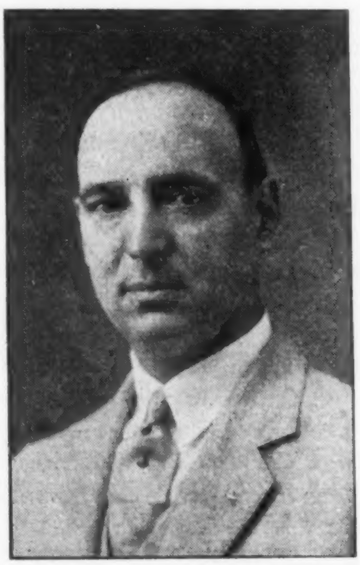
2. The time of pressure application is fixed
3. The applied load is constant
4. The time of application of the applied load is fixed.

These factors will remove operating variables and standardize the Brinell hardness test.

THE AUTHOR

Howard M. German is metallurgist with the Universal Steel Company of Bridgeville, Pennsylvania, which position he has held since 1924.

He was born at Doylestown, Pennsylvania, and in 1907 received the degree of Bachelor of Science from the department of metallurgy at Pennsylvania State College. He received his Master's Degree in 1913. He was, from



H. M. GERMAN

1910 to 1911, professor and head of the department of metallurgy at the South Dakota School of Mines. From 1912 to 1922, he was metallurgist with Henry Disston and Sons, Inc., Philadelphia, and from 1923 to 1924 he was production manager of the Ohlen-Bishop Saw Company at Columbus, Ohio. He is a member of the Pittsburgh Chapter of this Society.

DISCUSSION

Written Discussion: By Herman A. Holz, Testing Engineer, New York, N. Y.

Following an invitation received from Mr. Bird, the president of the

Society, I should like to say a few words in regard to Mr. German's paper which contains many ideas of considerable practical value and importance, since the standardization of the various conditions under which any mechanical test is performed is most essential.

There is hardly a subject in the entire field of mechanical testing which lends itself so readily to controversy and discussion as the problem of hardness testing and of the correct technique of performing these tests. Every paper and discussion on this subject brings out different points of view and usually assists in clearing up a rather complicated situation. My discussion is submitted in the endeavor to clear up some points which Mr. German has brought up in his paper.

Referring to the first paragraph of the paper under discussion, it is essential to keep in mind that the Brinell test has been developed and serves to yield data of a comparative nature on the hardness of ductile materials by measuring their resistance to "permanent" deformation under certain specific testing conditions. The permanency of the deformation, in this case a spherical impression, is quite important; it forms the basis of the measurement of the deformation by measuring the permanent diameter of the indentation produced.

The Hultgren Brinell balls mentioned by Mr. German are now in extensive use in this country and are giving good service. Their development represents a distinct advance in the art of hardness testing. The etching of Brinell balls to produce clearer outlines of the spherical impressions is an American development. If I remember correctly, it was first undertaken at the Bureau of Standards in 1915 or 1916. To show how some of the discussions on hardness testing lead to splitting hairs, I remember that after Dr. Hultgren read the paper on his new and improved Brinell balls before the Iron and Steel Institute of London, one of the most prominent British metallurgists, a man whom we all esteem highly in this country, got up and criticised the etching of the balls since the load required to force an etched ball into a metallic surface was greater than that required by a polished ball. So here we have a sixth point to add to Mr. German's list of variables in the Brinell test: the particular degree of polish or etching of the balls and the frictional differences caused thereby.

I have made a large number of Brinell tests by means of etched balls, polished balls, with and without oil, and have never been able to detect the slightest difference due to such theoretically variable friction. The etched Hultgren balls give clear and easily measurable impressions, and this advantage appears particularly in tests of hard steels.

Mr. German states that "the Brinell test has its limitations in that the only articles that can be tested are those that will stand permanent deformation and those that are of sufficient thickness and hardness that the force of penetration will not show a bulge on the opposite side of the test piece". This is not a limitation of the Brinell test, but is fully in accordance with our standard definition of "hardness" of ductile materials: their resistance to permanent deformation. It is an important advantage of the Brinell test that the load ratio can be varied to suit abnormal testing conditions as to

the thickness of the sections to be investigated, without interfering with the accuracy of test results. If a load is applied which is equal to 30 times the square of the diameter of the ball used, the hardness values obtained will always represent standard Brinell units. For instance,

a load of	on a ball of
30 kg	1 mm diameter
120 kg	2 mm diameter
750 kg	5 mm diameter
3000 kg	10 mm diameter

give identical results on the standard Brinell hardness scale. In the standard Brinell test of steel sections, we do not have to use different scales which have no relative meaning, but we are in a position to obtain test figures on one definite hardness scale, no matter whether the steel is thick or thin, soft or hard. Of course, I do not recommend the use of small steel balls unless the dimensions of the section under test make the use of such small indenting tools imperative. Dr. Brinell knew well what he was doing when he selected the 10-mm ball as standard indenting tool for hardness testing: it gives information on the average hardness over a good sized area, i.e. the ''macro-hardness'' of the material. For all practical purposes, it is this ''macro''-hardness, and not the ''micro''-hardness, which we have to know and to keep under control. For this reason, small indenting tools should always be avoided in hardness testing, unless testing conditions make their use necessary. It is well to keep in mind that even in the latter case are we able to obtain test figures in standard Brinell units, if the correct ratio between load and ball diameter is applied.

Referring to the classification of various types of ball indentation hardness testing machines which Mr. German gives in his paper, I desire to call attention that one important type has been left unmentioned: I refer to those machines in which calibrated, elastic media are used to measure or limit the test loads applied. Some useful machines constructed on this principle are being made in England (Thos. Firth & Sons), France (Guillery), Belgium (Dérihon), Switzerland (Amsler), etc.

There is a slight mixup in Mr. German's classification, especially in view of what he says later. In some of the machines which he mentions the load is not applied by weights and levers or weights and eccentric, but is applied by hand or motor power, usually through crank and gearing, and is measured by the weights and levers. I refer particularly to those machines in which the test piece is pushed upward against the ball (Riehlé, Alfred Herbert, etc.); in all these machines the test pressures are produced by hand or motor power and are then measured by weights. The same is true in all machines which use elastic dynamometers; the dynamometers do not produce the load, but only measure and indicate, sometimes limit the loads which are being applied.

In the hydraulic machines mentioned by Mr. German we must differentiate between ''primary'' and ''secondary'' gages. Nearly all these machines are provided with two gages: mostly one primary (dead weight pis-

ton) gage and one secondary (calibrated spring or Bourdon) gage. One primary gage alone is perfectly sufficient in a testing machine, while two secondary gages are no better than one secondary gage. To explain the difference between a primary and a secondary gage, for the measurement of pressures, all that is necessary is to recall the definition of "pressure". If pressure is the force acting upon unit area, the problem of its measurement is resolved into the determination of the force acting upon a known area, for instance on a piston. In engineering, there are only two types of primary gages, viz. a column of mercury and a loaded piston. All secondary gages must be calibrated by such primary standards, and naturally it is always advisable to use the primary standard directly, in the testing of materials, since its use insures accuracy and constancy of calibration. If Mr. German says that pressure gages do not permanently retain their accuracy, he naturally refers only to secondary pressure gages. The primary gages, if correctly designed and constructed, are not subjected to wear and tear and remain perfectly constant.

Mr. German claims that the loaded piston gage, a universally adopted primary standard in engineering measurements, possesses the "disadvantage of overloading, as an extra pressure is necessary to overcome inertia in raising the weights and that there is an extra pressure due to the rising and falling motion of the check weights in reaching equilibrium". I would like to ask Mr. German whether he has ever undertaken a series of tests to determine the presence and extent of these "extra pressures" which he mentions, or whether he is only presuming their existence.

I have made hundreds of measurements to investigate this particular point and can state definitely that as far as the genuine Brinell machine, made by the Alpha Co., is concerned, not the slightest inertia effects are present or perceptible, if the usual load rate of 100 kg per second is applied when the test load is nearly approached. If some operator should abuse the machine and apply a more rapid rate, the maximum inertia effects he could possibly produce by a perfectly crazy testing speed would still be below 1 per cent (30 kg at 300 kg), at a load rate of 500 kg per second. The test pressure remains perfectly constant as long as the piston floats, no matter whether it floats high or low, and if the machine is operated correctly, there it no such thing as a rising and falling motion of the weights in reaching equilibrium.

Only a few months ago, I shipped one of the genuine Brinell machines, out of regular stock, to the Bureau of Standards for calibration by means of their verifying ring, calibrated by dead weights up to 3000 kg. I do not believe that I violate any rule of ethics if I mention the following figures from the Bureau of Standards report, for the purpose of this scientific discussion:

"The error of the Alpha Brinell machine was measured by observing the difference in load between the load indicated by the Alpha machine and that indicated by the verifying ring. The errors are given in Table 1.

"In Table 2 are given the results obtained when the load was applied repeatedly.

Table 1.
Errors of Alpha Brinell Machine

load	Readings of verifying ring in dead weight machine	Readings of verifying ring in Alpha machine	errors of Alpha machine
500 kg	21.6	21.6	0 kg
1000 kg	42.9	42.85	- 1.1 kg
1500 kg	64.25	64.2	- 1.1 kg
2000 kg	85.3	85.25	- 1.1 kg
2500 kg	106.45	106.45	0 kg
3000 kg	127.6	127.6	0 kg

Table 2.
Reproducibility of Results
Repeated Loadings

test No.	load	load determined by the verifying ring
1	3000 kg	3000 kg
2	3000	2998
3	3000	3000
4	3000	3000
5	3000	2999
6	3000	2999
7	3000	3000
8	3000	2999
9	3000	3000
10	3000	2999

If Mr. German's statement regarding the overload and extra pressures were correct, the tendency in repeated loadings, Table 2, would naturally be on the other side of 3000 kg, i.e. above and not below.

I do not want to claim that all hydraulic machines of this type possess this high accuracy and freedom of inertia effects, but I do claim it for the genuine Brinell machines. Some of the counterfeit machines, usually containing leather packing, piston rings, also an entirely different kind of piston in the dead weight gage, are very unsatisfactory and inaccurate.

Mr. German has not mentioned in his paper a common source of error in Brinell testing: the contact pressure between the ball and test piece. There is a considerable leverage on the hand wheel, and I had occasion to make some measurements of these contact pressures applied in routine testing in several plants, during recent months. In many cases the loads applied varied between 30 and 50 kg. I am mentioning this point particularly, since in all machines in which the testpiece is pushed upward, i.e. in which the load is applied from below the testpiece, this tightening pressure is automatically included in the load measurement. If the load comes from above, through the ball to the testpiece, this initial loading in setting is often a source of considerable error. For this reason, I am of the opinion that of the two types of dead weight machines mentioned by Mr. German the one

in which the testpiece is forced upward into the ball is superior to the ones in which the load is released downward on the ball. The inertia in lifting or swinging the weights is negligible compared to the error produced by the tightening pressure. All these dead weight machines possess other disadvantages and sources of error which make their use less desirable than that of the genuine Brinell machines, of hydraulic construction. I am much opposed to making such machines entirely automatic unless routine tests of large quantities of metal products require a high speed. It is much better for the engineering profession to build up a staff of trained testing engineers who watch their step and consider carefully what they are doing instead of being trained to push a button. If rapid routine tests are required, every genuine Brinell machine of hydraulic construction can be operated by means of a motor-driven cam pump, automatically increasing the load, maintaining it for a desired period and automatically releasing it. All that is then necessary is to insert and remove the test pieces. There is no opening or closing of valves, no pushing of buttons, etc., while the accuracy obtained is guaranteed to equal that of careful hand operation.

The general tendency in the installation of testing machines favors decidedly the use of well-built hydraulic machinery, not only in hardness testing but in tensile testing as well. If hydraulic machines are built without packing, diaphragms, knife edges and similar elements subject to wear and tear, and if the loads applied are automatically balanced against an invariable primary standard of load measurement, they are far more constant, much easier to operate, and in general much more satisfactory than the horizontal lever and knife edge machines.

I would like to close my discussion of Mr. German's interesting paper with the statement that in all the 26 years, since Dr. J. A. Brinell first developed his original hardness testing machine in 1900, it has never been necessary or possible to improve upon his original design and to duplicate the accuracy and constancy of the genuine Brinell machines.

Written Discussion: By L. A. Lanning, Metallurgist, New Departure Manufacturing Company.

The title of this paper seems to be slightly misleading in that the author has considered under the title of "Standardizing The Brinell Test" only one phase of the matter, namely: the machine itself, while any or all of the standard machines on the market may be subject to error, within the ordinary ranges of hardness these errors are slight.

I have personally made hundreds of tests using a small portable Brinell machine, which applied the load by means of a cam arrangement, the intensity of load applied being governed by a series of saucer-shaped springs. As liable to error as this machine appeared to be, frequent tests found it to consistently maintain its accuracy. I believe that the machine in itself is quite likely to give us the least amount of trouble.

The Brinell ball itself is one source of possible error, particularly for hardened material. We all appreciate the difficulty in hardening several pieces of the same material to an absolutely uniform hardness. How then may we hope to obtain Brinell balls of such uniformity that we can obtain

accurate readings over all ranges? This variation in Brinell balls has its influence, especially on hard material.

The second factor effecting the Brinell reading, deals with the surface of the material and the actual reading of the impression. The surface of the piece to be tested should be quite carefully prepared, scratches of any appreciable size are apt to cause variable and inaccurate readings.

On annealed high carbon steels in particular care must be taken to remove sufficient depth of metal from the surface before making the Brinell impression or the influence of decarburization is apt to be reflected in the reading.

Another and, I believe, vital cause of variables in the Brinell test, lies in the human equation. It is quite diffcult to get two observers to make the same reading on a Brinell impression, even with the microscope reading glass. Experience in our own shop has brought this forcibly to my attention. I have frequently witnessed variation of one division between two operators, an error greater than is liable to creep in due to the machine or to method of load application.

I do not wish to dispute Mr. German in that there are possibilities for inaccuracies as he has indicated but I feel that he has touched the minor factor in the standardizing of the Brinell test and that the principle variables found in actual testing conditions are most apt to lie outside the possibilities touched upon by Mr. German.

Written Discussion: By S. P. Rockwell, Hartford, Conn.

Mr. German has brought out very well the deficiencies in making accurate Brinell tests. If commercial users of Brinell-type testers would realize the truths of which Mr. German brings out, less confusion would exist in practice. Hardly one concern in ten pays any attention to overloading or to the time element or to the condition of the Brinell ball. Another point which is often neglected is that the Brinell impression is often oval in shape due to grain of metal tested, the average operator bases his results on one diameter reading.

Brinell machines when sold have precautionary directions to prevent all these points, but it is apparently an error for one to read directions and apply the import.

The improved Brinell machine described by Mr. German eliminates the time and overloading factors. The operator must, however, watch the other errors mentioned.

The Rockwell tester in its early inception realized the time and overloading element and has endeavored to safeguard these points.

I am glad to note that Mr. German uses impression diameters as his hardness figure rather than the calculated Brinell number. Diameters are progressive by a uniform difference and mean more to the layman than Brinell numbers which progress by increasing differences.

Written Discussion: By L. B. Tuckerman, Assistant Chief, Division of Mechanics and Sound, Bureau of Standards, Washington, D. C.

We agree fully with Mr. German in his statements of the conditions necessary to secure closely consistent Brinell readings. These may be stated:

1. A sufficiently hard ball;
2. A ball sufficiently close to the required diameter;
3. A sufficiently uniform rate of application of load;
4. A sufficiently accurate and constantly maintained maximum load;
5. A sufficiently constant time of application of the maximum load.

1. Mr. German does not state whether balls showing 64 to 67 Rockwell cone represent satisfactory hardness for ordinary use. Presumably he thinks the Hultgren work-hardened balls the most satisfactory. Do these show 64 to 67 Rockwell cone? Is the Rockwell cone a satisfactory measure of a suitable ball?

2. This is not discussed here, presumably covered in his other publications.

3, 4, 5. We agree that these are not automatically provided for in the present commercial machines. That, however, does not prevent a careful operator from maintaining these conditions satisfactorily with machines now on the market. It is of course convenient for the operator to have all these things provided for him, and presumably in laboratories where Brinell tests are routine the extra money would be well invested. It is not, however, just to condemn machines as **incapable** of accurate use because a careless operator can misuse them.

We do not agree that a compound lever machine with a downward motion of the weights prevents overloading. The deceleration of falling weights produces overload by the necessity of overcoming inertia just as well as the acceleration of rising weights.

There are on the market both hydraulic and compound lever "rising weight" machines on which a careful operator can apply the load at any reasonable rate he desires and maintain the maximum load constant with all needful accuracy for any required time within any reasonable limits of accuracy.

The prevention of overloading by "overcoming inertia" or by "swing of the weights" whether in a "rising weight" or "falling weight" machine is solely a matter of preventing undue acceleration (or deceleration) of the weights. There is no principle involved either in "hydraulic" machines or in "rising weight" machines which would prevent their being fitted with automatic mechanisms which would accomplish all, in the way of control of rate of loading and maintenance of an accurate maximum of load for a constant length of time, which is accomplished by Mr. German's machine.

Mr. German has produced a very ingenious and convenient machine which will relieve the operator of much of the care now necessary to secure reproducible Brinell numbers. The foregoing criticism does not in any way affect the usefulness, convenience and accuracy of his machine.

The criticism is made solely to correct his statement:

"A review of different devices for applying pressure shows that only one, the first type of the weight and lever machine will give an accurate and constant pressure."

If uncorrected, it might unduly prejudice readers against other equally accurate—though not necessarily as convenient machines.

One minor additional comment may be made. The cam mechanism he describes does not, as might on casual reading be inferred, provide for all tests, the same rate of pressure application, the same time of pressure application, and the same time of application of the applied load. Other things being equal the lower the Brinell number and the more flexible the piece tested, the slower will be the rate of pressure application, the longer the time of pressure application, and the shorter the time of application of the full load. These are all, as he states fixed by the machine, and would within the limits of accuracy of the machine be the same for duplicate tests on duplicate specimens, but would be different for different specimens. The differences, however, are in all probability so small as to have no appreciable effect on the readings obtained.

Written Discussion: By S. N. Petrenko, Associate Mechanical Engineer, Bureau of Standards, Washington, D. C.

(1) It is stated in this paper that "if pressure is applied rapidly, the depression will be greater". Is this statement based on experimental results?

Experiments made at the Bureau of Standards did not show this to be true for all tested metals. Neither can we see why this should be true theoretically. Different metals may respond differently to the rate of cold working.

(2) Numerous experiments, among them those made at the Bureau of Standards, have shown that the diameter of indentation continues to increase perceptibly for at least 2 or 3 minutes (not 45 seconds as stated). Some authors recommend as much as 5 minutes for accurate tests. However, we agree with the author that the practical limit is much lower.

(3) The improved Brinell machine does not entirely solve the problem of automatic standardization of rate and time. The moment when the cam leaves the roller is not fixed; it depends upon the depth of indentation. For hard materials it will come earlier than for soft materials with the result that for hard materials the rate is more rapid and the time under load is greater, than for soft materials.

Written Discussion: By H. L. Whittemore, Chief, Engineering Mechanics Section, Bureau of Standards, Washington, D. C.

Mr. German's paper takes up a subject which is of great importance to all materials engineers. The wide use of the Brinell test in the determining of the suitability of a material for the intended purpose emphasizes the importance of keeping the errors small.

It should not, by any means, be considered that this paper discusses all the errors which may occur nor their magnitudes.

To the list on page 54, should be added:

- The size of the softer specimens, particularly the thickness.
- The diameter of the hard object.
- The character of the surface of the soft material.
- The accuracy of the apparatus for measuring the diameter of the indentation. This, in turn, depends somewhat on the lighting conditions.

It would seem that no discussion of the errors in Brinell numbers was complete without some consideration of these matters.

Unfortunately, it has been found that the hardened steel balls used in the Brinell test do deform permanently, at least when used on material having a high Brinell number, say 600 B. n.

I was under the impression that the standard load for soft materials was 500 kilograms, not 1500 kilograms as given in this paper.

We have been studying the errors in Brinell tests for some time in our Engineering Mechanics laboratory at the U. S. Bureau of Standards and our experience does not entirely confirm Mr. German's conclusions that accurate results cannot be obtained with Brinell machines for which pressure gages are used to measure the load. These machines have given a good account of themselves and if a Proving Ring[1] is used to calibrate them from time to time should give accurate results. The fact that a careless operator may over or under load the specimen may make it advisable to use some other type of machine but that is a different story.

We have found the inertia forces in the machines having check weights to be small although precautions should be taken to prevent their exceeding permissible magnitudes. This affers no practical difficulty.

Mr. R. L. Templin[2] uses an Eastman photo timer for applying the load the desired length of time. We have followed his example and find it satisfactory.

The author of this paper gives sound reasons for believing that errors exist in most Brinell machines but only for the rate of application of the load and for the time under maximum load does he give experimental data upon the amount of the errors.

With the Brinell proving ring he can measure many of them and then decide whether or not they are serious.

The Brinell machine which he recommends is designed on sound principles and should, apparently, give correct readings but other types of Brinell machines also give correct readings. Why discard them? The fact that Mr. German's machine is for the most part automatic is an advantage particularly if a large amount of work must be done with unskilled help. One cannot help wondering whether an appreciable error does not result from the use of ten (if I count correctly) bearings in the lever mechanism. Dirt often increases the friction even if they are knife edges. Personally, I should prefer to use plate fulcrums following in the footsteps of A. H. Emery, the illustrious designer of the largest precision testing machines in this country.

Lastly, brethren, I beseech you to consider carefully before you accept the last statement, "These factors will remove all variables and standardize the Brinell hardness test". It's a large order and no machine will make intelligent supervision unnecessary.

Oral Discussion

A. L. Davis: Mr. Chairman and gentlemen, I want to add my evidence

[1]See "Elastic Ring for Verification of Brinell Hardness Testing Machines," Transactions, American Society for Steel Treating, March, 1926, Vol. IX, No. 3, p. 420.

[2]Chief Engineer of Tests, Aluminum Company of America.

in corroborating what Mr. German says about hand pump machines producing overload. I ran into trouble when I thought I was trying to be careful. I discovered later that I was not quite careful enough and I have gotten too large readings. (diameter of impression).

As to the lever-type machines, I think they have proved disappointing. I have operated them in years gone by, and had expected very much when getting them but was disappointed in their use, so much so that I have some feeling that the best path out does not lie by way of levers.

To the design which Mr. German is suggesting I think there is an objection. With the top lever the multiplication will be exact only when it is horizontal, and, of course, the position of that top lever will vary a little bit according to whether very hard or very soft material is being tested, as it must accommodate itself to the movements of the ball into the specimen.

From the information that has come from those who have used the power driven hydraulic machines which have a safety release valve so that the pressure of the oil cannot exceed a certain amount the reports seem to be excellent. They are rapid, of course, bringing the pressure up to a 3,000-kilogram load in from one second (on very hard material) to not exceeding three seconds (on the softest steel), the extra time being required to pump the oil for the added piston travel for deep impressions.

The question is going to arise as to whether that extremely rapid loading is satisfactory. Practically, the users consider that it is; but work will have to be done to prove it. But it is a great thing to be able to get your pressure almost immediately, and it is very possible to regulate then the time that you allow it to stay on. With rather hard materials, heat treated materials, in practice I think they find that in a short time, as, for instance, five seconds, it appears to give then standard or, at least, constant results.

H. M. German: In reply to the written discussion of Mr. Holz, I have not conducted any actual tests to find out what is the exact amount of overloading which may be produced in operating the hand pump type of Brinell machine, but if the gage is any indication, I have seen operators apply the load so rapidly that they would produce at least a 200-kilogram overload. I am certain that when we have a rapid application of pressure, it assumes more of the nature of an impact, and we have found that on soft materials we would get as high as two-tenths of a millimeter difference in actual readings. If all operators applied a pressure at the rate of 100 kilograms per second when the test load is nearly approached, the error of overloading would be minimized, but in actual practice we know that this is not done. If a number of test pieces are ahead of a man out in the operating department where he has to keep up with production, you know he is going to get through with them in a hurry; therefore the tests are not standardized.

Also, when operating hydraulic machines in the production departments during the winter months it is oftentimes necessary to thaw out the machines before work can be started. The conditions are entirely different when the machines are operated in a well-heated laboratory. I have observed tests made on a cold machine which I thought were incorrect, and upon taking the pieces into the laboratory and retesting them have ob-

tained entirely different results. These errors would not occur with the type of machine as described in the paper.

So far as the results which Mr. Holz gives in his paper, I would not question the accuracy of any new Brinell machine which had been recently calibrated, particularly when the tests were made under ideal conditions as conducted by the Bureau of Standards; but if the tests were made on a machine after it had been in service for a number of years, and if it were conducted by the average shop man in the same manner as he would proceed in making a regular production test, I feel confident that the figures given by Mr. Holz would not be duplicated. Of course, the tests as made in everyday practice in the shop must be made by the shop men, for high salaried, trained engineers cannot be used for production work.

I might also add that I have seen many so-called trained engineers who did not regulate the speed of load application or the time in which the load was applied in making the Brinell test. Therefore, I feel that anything we can do to eliminate the personal equation in making the Brinell test will tend to standardize the test.

In reply to the criticisms of L. A. Lanning may I say that the paper deals not only with machine design but also the personal factor in conducting the test. The extent of error is largely governed by the care and accuracy used in making a test. Therefore if a machine is designed to eliminate the personal factor and at the same time apply an accurate load it is a decided advance toward obtaining accurate and consistant results.

The error due to variation in the hardness of Brinell balls is slight as balls can be purchased which are uniform in hardness and accurate to size.

It cannot be questioned that the surface of the specimen at the area of test should be flat and free from deep scratches in order to obtain accurate readings and it is recognized that decarburization will effect the amount of deformation.

Errors in reading the diameter of the depression can be largely eliminated by the use of an illuminated magnifying glass, which will give a clear definition, and by taking two readings at right angles from each other to see that the depression is round. Oval depressions are not accurate and should be discarded.

I do not agree with Mr. Lanning that a greater error is caused by incorrect reading of the diameter of depression than in the design and manipulation of the Brinell Machine. I have frequently observed variations as great as 0.2 millimeters due to too rapid application of load and overloading, whereas the error in reading the depression should be less than 0.05 millimeter if the surface has been properly prepared before making the test.

THE TENSILE PROPERTIES OF STAINLESS IRON AND OTHER ALLOYS AT ELEVATED TEMPERATURES

By P. G. McVetty and N. L. Mochel

Abstract

The tensile properties of annealed stainless iron and hot-rolled Monel metal at temperatures up to 500 degrees Cent. (930 degrees Fahr.) are discussed and compared with similar properties of seven other materials.

Charts are presented to show that a comparison of the normal temperature tensile properties of materials does not indicate their relative value at elevated working temperatures.

Data are presented to show the effects of sustained tension loading at a high temperature upon the tensile properties of materials at that temperature.

Requirements of apparatus for these tests are discussed in detail with special reference to the necessity for refinement of stress and strain-measurements.

A description is given of a modified form of the Martens extensometer which combines simplicity and ease of operation with a high degree of precision of measurement.

Introduction

REFERENCE has been made before this society (1)* to the investigation in process at the Westinghouse Research Laboratory of the effects of elevated temperatures on a certain grade of stainless iron and other alloys. The purpose of this paper is to discuss the results of this investigation; to add to the data which have already been published (2) and to stimulate discussion of test methods.

Analysis and Heat Treatment

The analyses and heat treatments of all materials referred to in this paper are given in Tables I and II of the Appendix.

Properties of Materials at Various Temperatures

In the following paragraph the physical properties of annealed

*The figures appearing in parentheses refer to the list of references appended to this paper.

A paper presented before the eighth annual convention of the Society, held in Chicago, September 20 to 24, 1926. Of the authors P. G. McVetty is mechanical engineer, research department, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa., and N. L. Mochel is metallurgical engineer, South Philadelphia Works, Westinghouse Electric and Mfg. Company.

stainless iron and hot-rolled Monel metal at elevated temperatures are given and a comparison is made with similar properties of seven other materials.

(1) *Annealed stainless iron* (*Material G.*) Fig. 1 shows the appearance of the fractures of this material as obtained in the short-time tests at elevated temperatures.

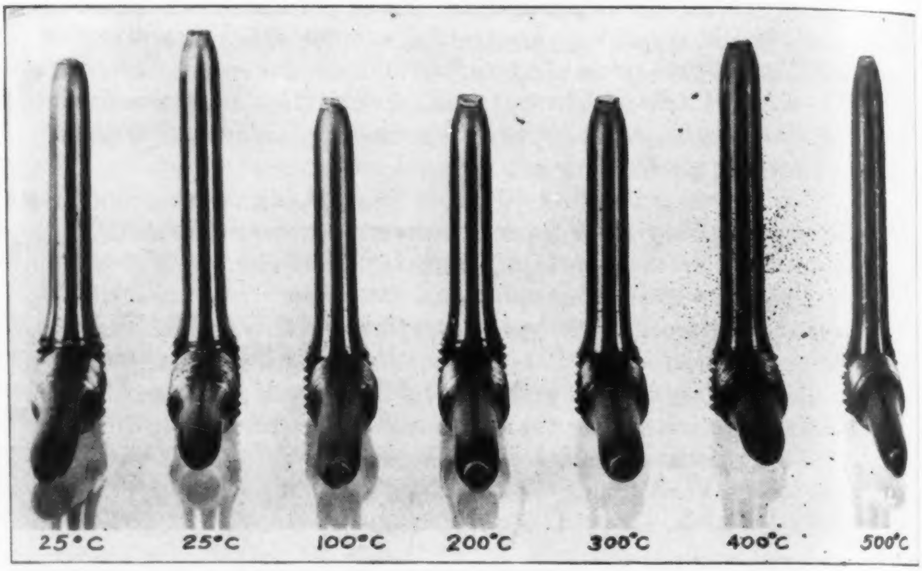


Fig. 1—Fractures of Annealed Stainless Iron—Material G.

Fig. 2 shows the tensile properties at these temperatures. As has been reported (2) for the heat treated condition of this material, the properties are affected in a less degree by high temperature than any of the other materials examined.

(2) *Monel Metal* (*Material L.*) Fig. 3 shows the appearance of the fractures of this material as obtained in the short time tensile tests at elevated temperatures. Both tests at 930 degrees Fahr. (500 degrees Cent.) show the same peculiar type of fracture which is entirely different from the appearance at 750 degrees Fahr. (400 degrees Cent.) and lower temperatures.

Fig. 4 shows the tensile properties at these temperatures. It is evident that a marked decrease of ductility occurs at 930 degrees Fahr. (500 degrees Cent.) which would account for the appearance of brittleness in the test at that temperature.

(3) *Comparison with other materials.* In Figs. 5, 6, 7 and 8 the main physical properties of annealed stainless iron (Material G)

and hot-rolled Monel metal (Material L) are compared with seven other materials over the range of temperature studied. These charts are self-explanatory and the relative value of the various materials may be readily compared. For example, it is evident that the strength of heat treated stainless iron is superior to that of any of the other materials examined up to a temperature of 750 degrees

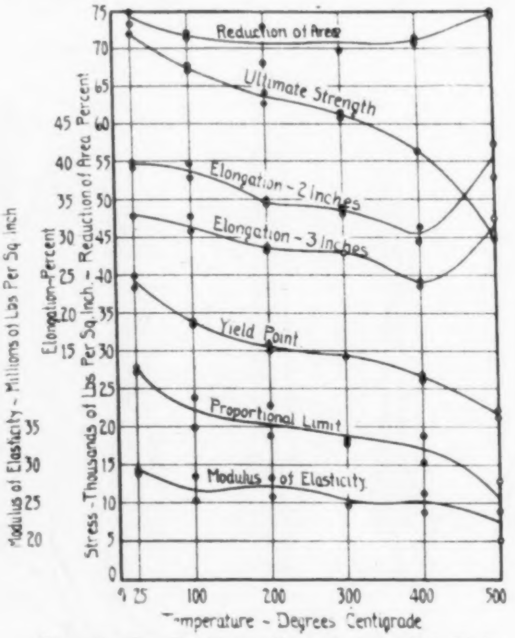


Fig. 2—Tensile Properties of Annealed Stainless Iron—Material G—at Various Temperatures.

Fahr. (400 degrees Cent.). This is shown by the comparison of ultimate strengths, proportional limits, and moduli of elasticity. Furthermore the ductility is extremely high and there is no tendency toward brittleness as is found in the blue heat range of medium carbon steel at about 525 degrees Fahr. (275 degrees Cent.). Between 750 and 930 degrees Fahr. (400 and 500 degrees Cent.) the ultimate strength is still higher than the other materials but it is generally conceded that working stresses at elevated temperatures for steady stress conditions must be based upon the proportional limits rather than the ultimate strengths.

Referring to Fig. 6, we find that most of the effect of heat treatment of stainless iron and of 5 per cent nickel steel is lost at 930 degrees Fahr. (500 degrees Cent.). The heat treated medium carbon steel retains some of the effect of heat treatment at 930 degrees Fahr. (500 degrees Cent.) and it is interesting to note that its pro-

portional limit is about the same as that of Monel metal which is higher at that temperature than that of any of the other materials examined.

It is usually considered that the properties of a heat treated steel will not be affected by a working temperature which is lower than the drawing temperature of the original heat treatment. This

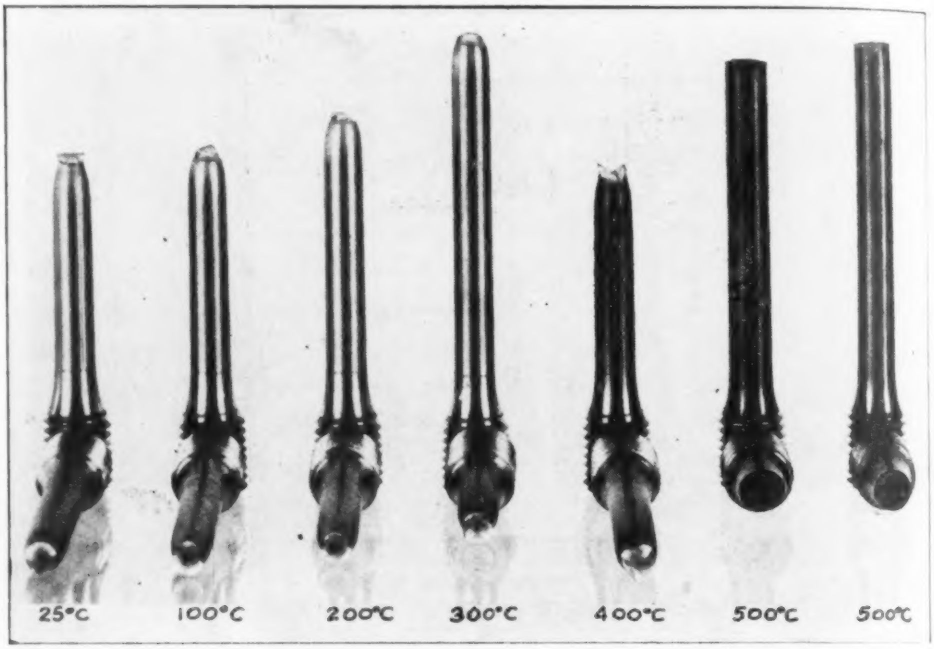


Fig. 3—Fractures of Hot-Rolled Monel Metal—Material L.

may be true if the time of exposure to the elevated temperature is short but the data presented here show that time and temperature are interrelated and a similar annealing effect may be secured by long exposure to a lower temperature as that obtained by the original short exposure to the drawing temperature. This condition is well known in the case of annealing nonferrous materials such as copper (3) but it is not so generally known that this fact may require consideration also in the heat treatment of steels for applications at elevated temperatures.

(4) *Effect of time element on physical properties.* The matter of deterioration of materials under exposure to elevated temperatures has been referred to by Fenwick (4), Mellanby and Kerr (5) and others, especially in connection with turbine blading. The short time tensile test cannot indicate the effect of such service

conditions upon the material. It is evident that a test which attempts to duplicate these service conditions involving effects of time, stress, temperature, corrosion and erosion would be long and complicated. We feel, however, that our long-time tensile tests

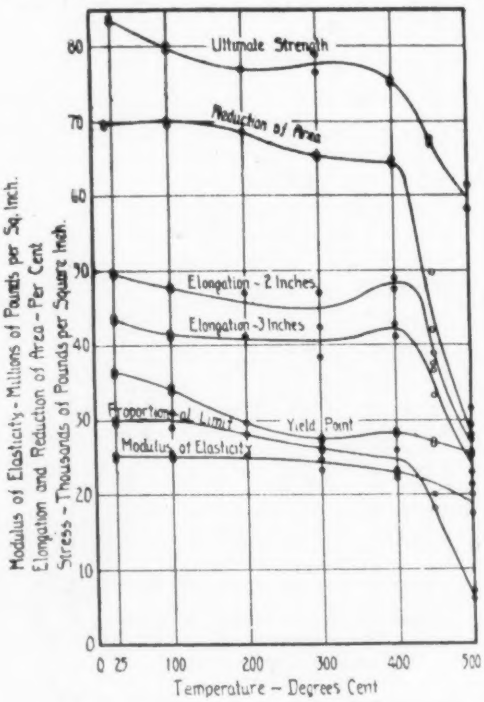


Fig. 4—Tensile Properties of Hot-Rolled Monel Metal—Material L—at Various Temperatures.

which include the effects of time, stress and temperature, yield considerable additional information and are a step in the right direction. Most of the long-time tensile tests which have been reported have considered only the measurement of extension of the test specimen while it is exposed to constant stress and temperature over various periods of time. Our tests measure this extension or flow to the nearest millionth of an inch and at the termination of the long-time test, a short time tensile test is made and the usual data obtained at the same temperature so that the tensile properties may be compared with those of the original material. This serves as a check on the possible deterioration of the material within the period of the long-time test. If the final strength is less than the original, it may be due to a slow annealing effect at the temperature of the test. If, as sometimes happens, the final strength is greater than the original, it may be due to strain hard-

ening caused by the extension and not relieved by the temperature of the test. One advantage of extreme refinement of strain measurement is that it allows a study to be made of these effects. (6).

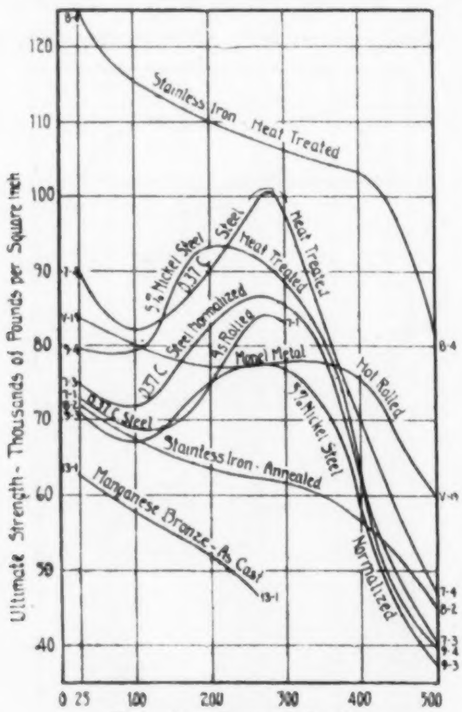


Fig. 5—Effect of Temperature on Ultimate Strengths of Various Materials.

In Table I there are given some data on the properties of stainless iron (Materials G and F) at 750 degrees Fahr. (400 degrees Cent.) before and after long-time tests at that temperature and various stresses.

Most of these preliminary tests were made at stresses below the proportional limit at the corresponding temperature. Under these conditions the annealed material shows practically no change of properties as a result of stressing at 750 degrees Fahr. (400 degrees Cent.) for a period of one month. At higher stresses in the preliminary test, the material was strain-hardened by the elongation and this hardening was not relieved by the temperature of 750 degrees Fahr. (400 degrees Cent.). This is shown by the increased strength and decreased ductility values of tests 1, 16 and 14.

Similar tests of the heat treated material (Table II) show considerable variation in the results. This is probably due to the

difficulty of securing absolutely uniform heat treated specimens. These tests are being repeated with a new lot of material and results will be reported later.

(5) *Brittleness at elevated temperatures.* Cases still exist where materials are applied to high temperature conditions with a

Tables I and II

Effects of Preliminary Loading at 750 Degrees Fahr. for Various Lengths of Time on the Tensile Properties of Stainless Iron

Table I

Material G—annealed

Test No.	Preliminary Loading in Long Time Test Lbs./ Sq. In.	° C.	Hours	P. L. Lbs./ Sq. In.	Y. P. Lbs./ Sq. In.	Ultimate Strength Lbs./ Sq. In.	Modulus of Elasticity Million Lbs./ Sq. In.	Elongation 2" %	3" %	Reduction of Area %
8-2-5	.....	...	0	22,500	27,000	55,750	26.8	29.5	23.7	71.6
8-2-6	.....	...	0	19,000	26,000	56,500	26.5	29.0	23.0	69.5
8-2-3	18,000	400	168	19,000	25,600	56,500	26.2	31.0	25.7	71.5
8-2-7	18,000	400	168	20,000	26,250	56,850	26.0	30.5	24.0	71.6
8-2-8	18,000	400	168	20,000	26,150	57,250	27.8	29.8	20.8	73.1
8-2-9	18,000	400	168	20,000	25,400	57,000	28.1	32.0	25.7	71.8
8-2-22	18,000	400	742	.....	.....	58,000	....	30.0	24.0	68.8
8-2-41	18,000	400	742	19,000	25,000	56,500	27.0	30.5	24.7	72.3
8-2-1	30,000	400	909	28,000	33,625	56,650	27.0	28.2	22.1	64.7
8-2-16	40,000	400	2,153	36,500	45,800	59,300	25.8	25.0	19.4	70.7
8-2-14	50,000	400	1,990	44,700	61,300	70,000	26.8	17.7	11.5	64.2

Table II

Material F—heat treated

Test No.	Preliminary Loading in Long Time Test Lbs./ Sq. In.	° C.	Hours	P. L. Lbs./ Sq. In.	Y. P. Lbs./ Sq. In.	Ultimate Strength Lbs./ Sq. In.	Modulus of Elasticity Million Lbs./ Sq. In.	Elongation 2" %	3" %	Reduction of Area %
8-4-32	.....	...	0	42,500	103,000	115,000	26.5	15.5	10.3	67.2
8-4-33	30,000	400	1	32,500	107,500	119,900	27.5	15.5	10.7	64.5
8-4-28	30,000	400	186.5	50,000	110,500	125,000	26.8	15.5	10.7	69.3
8-4-30	30,000	400	670	27,500	113,000	129,500	26.9	13.0	8.7	67.0
8-4-27	30,000	400	764	40,000	103,500	118,000	26.0	16.0	11.0	67.9
8-4-31	30,000	400	3,300	.....	......	114,750	....	15.5	11.0	61.1

Note—Since these long time tests were made on bars of standard diameter (0.505 inch) the question of effect of bar diameter can be excluded from this comparison. Some of the creep data for these tests have already been published. (6)

knowledge of the tensile properties at normal temperature only. Allowance is usually made for a decrease in strength but it is not so common to anticipate a decrease in ductility as the temperature is increased. This condition is noticeable in the "blue-brittle" range of ordinary steels at about 525 degrees Fahr. (275 degrees Cent.) and we find even more pronounced effects in brass at 750

degrees Fahr. (400 degrees Cent.) and in Monel metal at 930 degrees Fahr. (500 degrees Cent.). Fig. 3 shows two square fractures of Monel metal at 930 degrees Fahr. (500 degrees Cent.) even

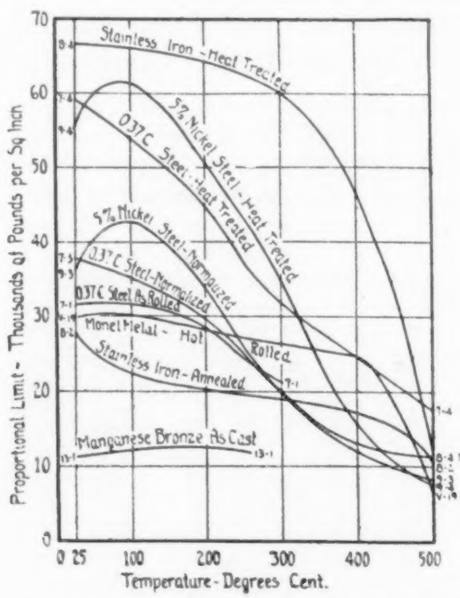


Fig. 6—Effect of Temperature on Proportional Limits of Various Materials.

though the ductility is high at 750 degrees Fahr. (400 degrees Cent.). When this condition exists, the fracture is liable to occur at any slight surface imperfection such as the grooves 0.002 inch deep used to locate the high temperature extensometer. This gives further proof that design data must be obtained from tests made at the temperature at which the material is to be used.

Equipment and Methods of Test

At the present time, the methods of tension testing at normal temperature are not completely standardized. At elevated temperatures, even greater differences exist and these must be considered in comparing the results obtained by different investigators. An excellent resumé of equipment and test methods was published in 1924 (7). Since that time additional information has been published by R. B. Wilhelm (8), H. J. French, (9, 10), V. T. Malcolm (11), L. W. Spring and J. Kanter (12), and others. (2) It is expected that there will be a gradual development of procedure which may eventually lead to standardization of test methods. To that end, and to stimulate constructive discussion, it appears desirable

to consider some of the details in which tests at elevated temperatures differ from the ordinary tensile test. It is attention to these details, some of which appear trivial which may mean the difference between success and failure in standardizing tests at elevated temperatures.

(1) *Furnace.* The matter of furnace design has been covered in the excellent paper by L. W. Spring and J. Kanter (12).

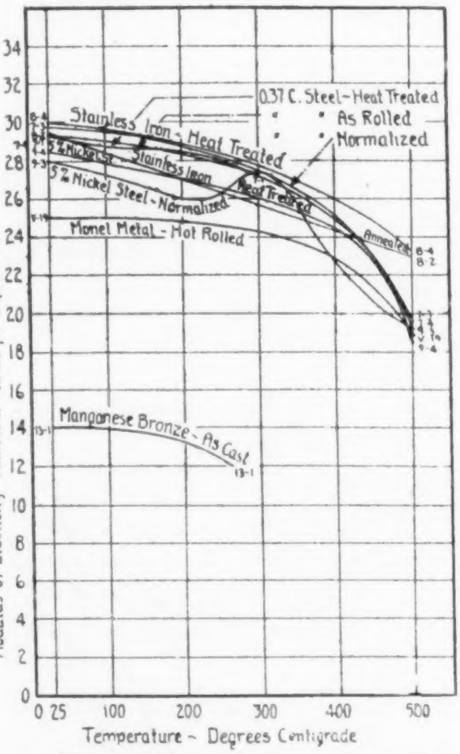


Fig. 7—Effect of Temperature on Modulus of Elasticity of Various Materials.

We have used a furnace of the type they recommend since the beginning of our high temperature work (8) three years ago and find it very well suited to our needs.

(2) *Temperature control.* Under ordinary conditions, extreme refinement of temperature control may not be necessary. When, however, test conditions require that strain measurements be made to the nearest millionth of an inch, it is evident that the expansion or contraction of the test piece resulting from very slight changes in temperature will affect these measurements. A gradual temperature change may change the slope of the stress-strain curve giving a false value of modulus of elasticity. A sudden temperature

change may indicate a false value of proportional limit. It has been shown (2, 6) that it is possible to control the temperature within 1 degree Cent. over long periods of time. A much closer control is necessary over the elastic range of a short-time test. For close control it appears desirable that at least 90 per cent of

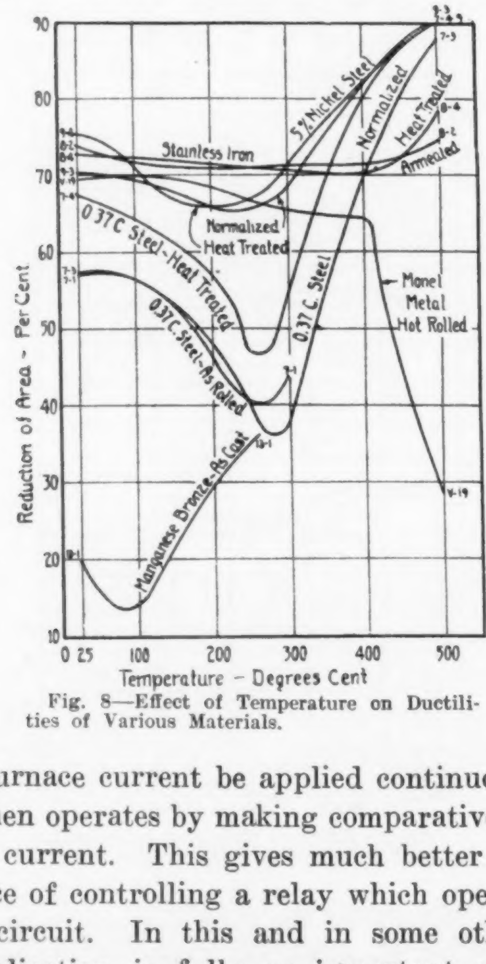


Fig. 8—Effect of Temperature on Ductilities of Various Materials.

the necessary furnace current be applied continuously. The automatic control then operates by making comparatively small changes in the furnace current. This gives much better results than the common practice of controlling a relay which opens and closes the main furnace circuit. In this and in some other respects, the method of application is fully as important as the characteristics of the control instrument itself.

(3) *Measurement of extension.* It has been shown (6) that the interpretation of results of long-time tensile tests at elevated temperatures is largely dependent upon the refinement of the measurement of extension. It will be shown that a similar condition exists in determining proportional limits of all materials at elevated temperatures and also at normal temperatures with some alloys such as stainless iron. We have found that the Martens mirror-type extensometer which reads to approximately four mil-

lionths of an inch gives good results in short-time tensile tests. When it is necessary to take successive readings over long periods of time it is almost impossible to prevent disturbance of this instrument. To avoid this difficulty, we have replaced the Martens telescopes by a specially designed projection apparatus on all of our long-time tensile testing machines.

Figs. 9, 10 and 11 show respectively photographs of the assembled projection instrument, the component parts of the instrument, and a cross sectional drawing of the parts in place. This is bolted rigidly to the frame of the testing machine. The lamp serves to illuminate the very fine cross-wires, the image of which is projected by the lens on the mirror and back on a scale on the opposite wall. This instrument is easily protected from disturbance, requires no additional floor space, can be made at small expense and its accuracy is somewhat better than that of the standard Martens apparatus. With scales fifteen feet from the mirrors, it is possible to read to the nearest hundred-thousandth and to estimate millionths of an inch.

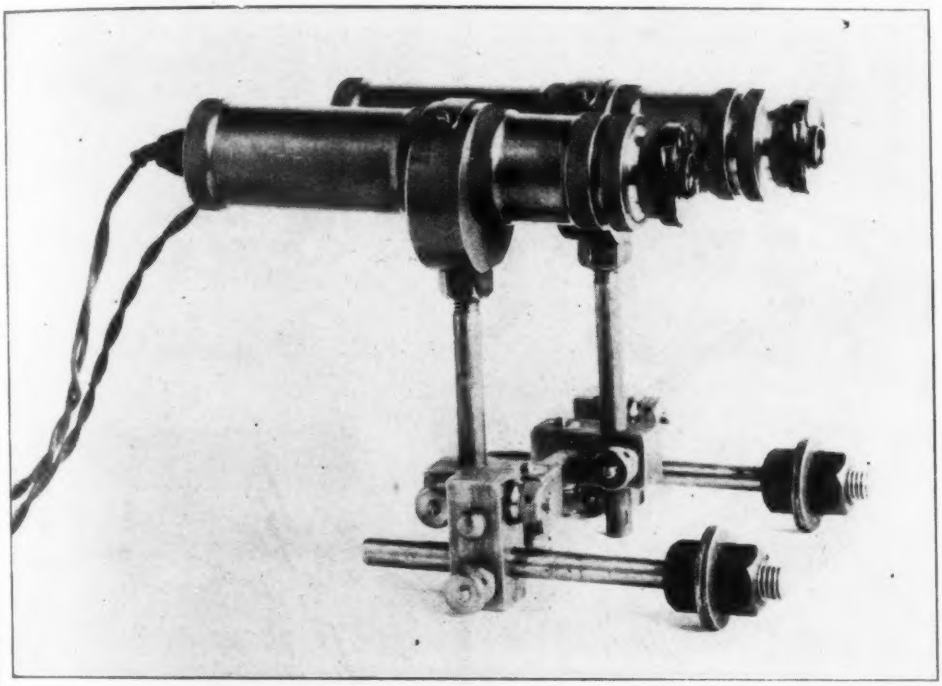


Fig. 9—Optical Extensometers with Adjustable Support.

(4) *Measurement of applied stress.* From the method of determining proportional limits recommended by the A. S. T. M.

(13) it is evident that the requisite accuracy of stress measurement is definitely related to the accuracy of strain measurement, and this relation depends upon the modulus of elasticity of the material being tested. (14, 15). In the use of this method it is specified that the sensitivity of the testing machine be not greater than 0.4

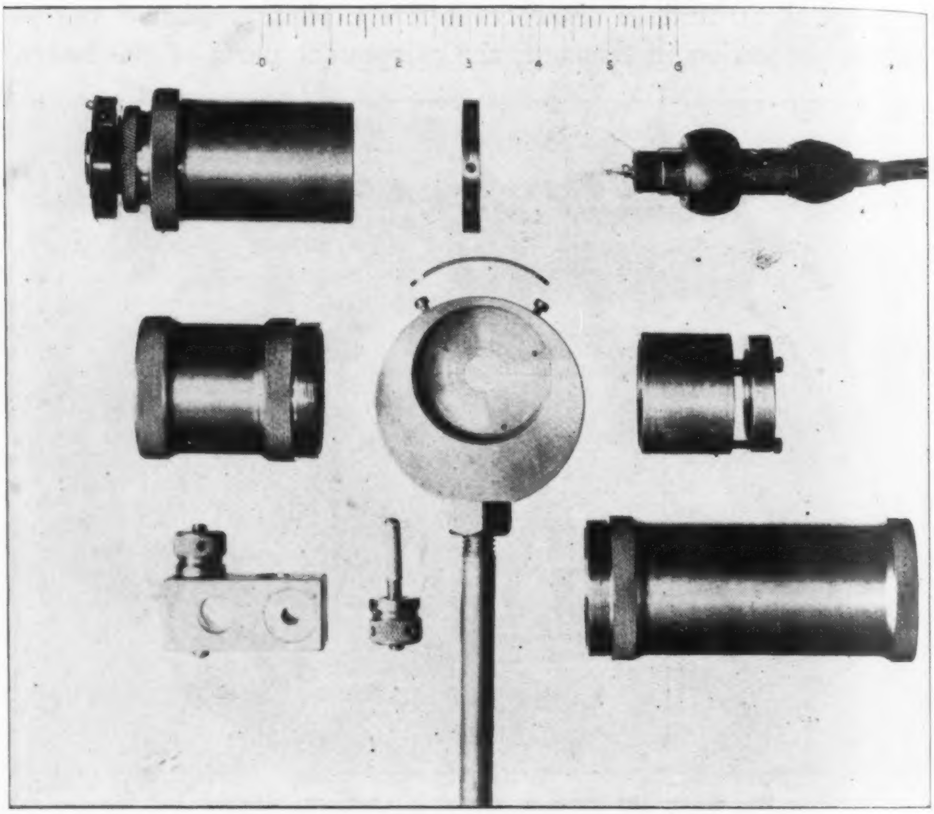


Fig. 10—Optical Extensometer Parts.

per cent. Applying this to an average value of proportional limit of 30,000 pounds per square inch, the machine must be capable of showing changes of stress of 120 pounds per square inch. For a modulus of 30 million, an error of this amount in the stress measurement will give the same apparent deviation from the elastic curve as an error of 4 millionths of an inch per inch in the strain measurement. It is therefore apparent that the advantage to be gained from precise measurement of strain is limited by the sensitivity of the testing machine used.

Commercial testing machines are allowed a tolerance of 1.5 per cent and a deviation from correct alignment of 0.01 inch. The

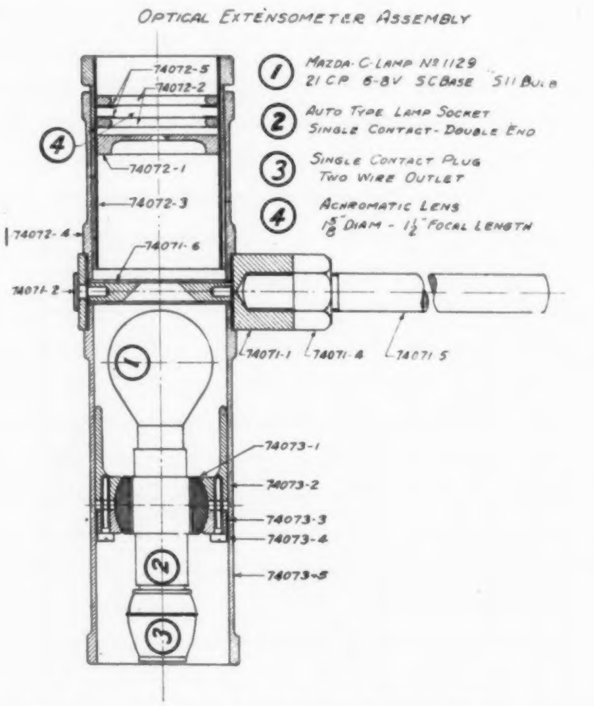


Fig. 11—Assembly Drawing of Optical Extensometer.

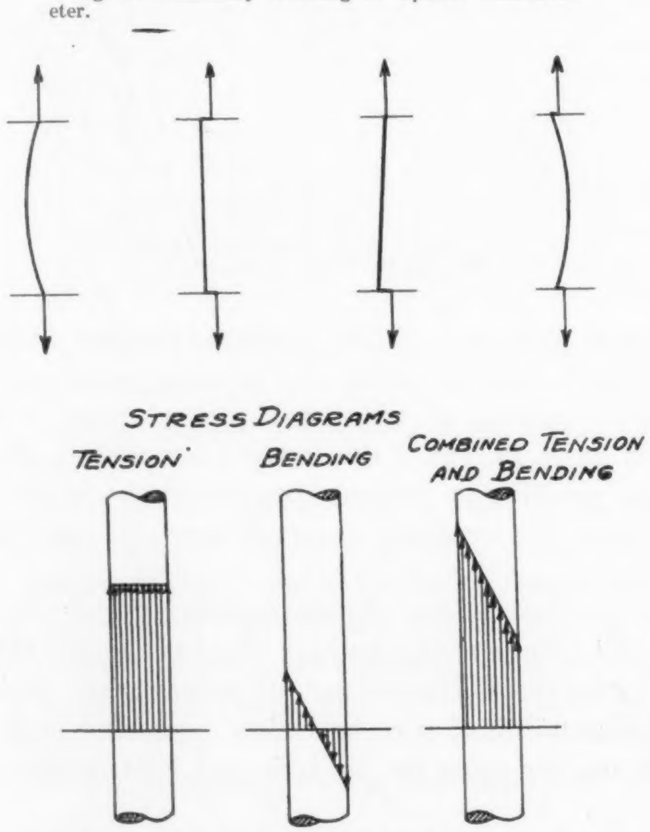


Fig. 12—Various Types of Eccentricity of Loading in the Tensile Test.

former represents a possible 1.5 per cent error in stress measurement. The latter is more serious as it has been shown (16) that this amount of deviation from correct alignment causes an increase of 15 per cent over the measured stress on a standard 0.505 inch diameter test piece.

Fig. 12 shows a few typical cases of eccentric loading includ-

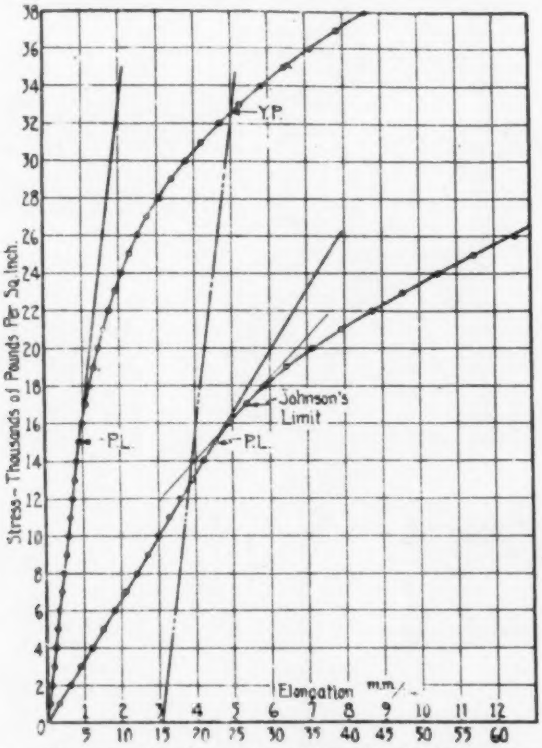


Fig. 13—Tensile Test of Normalized Medium Carbon Steel—Material B—at 400 Degrees Cent.

ing the bent test piece and various possible incorrect settings in the machine. In each case the stress may be resolved into components of tension and bending of which the former alone is measured. We have had cases in which this error amounted to 40 per cent and it is our practice to discard determinations of proportional limits in which the readings show evidence of eccentricity of loading.

(5) *Proportional limit determinations.* Work by Dr. McAdam (17) and by one of the authors (1) has shown that, in tests at normal temperature, the values of proportional limit, elastic limit, and Johnson's limit may be widely separated under certain conditions depending upon the analysis and heat treatment of the

material. This condition is known to exist at elevated temperatures also and tests indicate that the difficulty of determining proportional limits of all materials increases as the temperature is

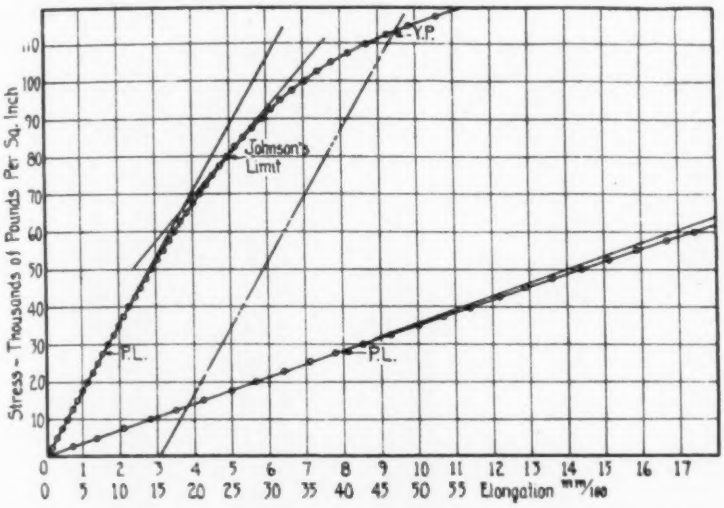


Fig. 14—Tensile Test of Heat Treated Stainless Iron—Material F—at 400 Degrees Cent.

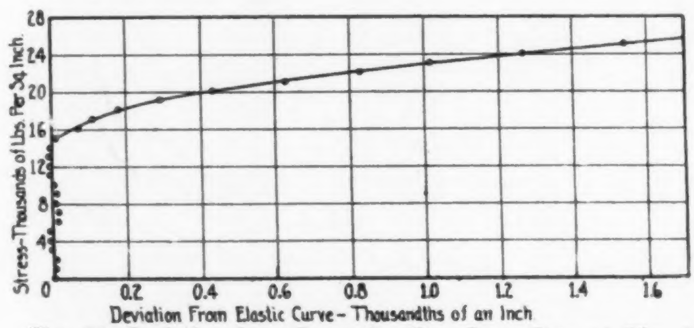


Fig. 15—Deviation from Proportionality—Same Data as Fig. 13.

increased. It follows that precise measurements of stress and strain are generally necessary for this determination at elevated temperatures and also at normal temperature for certain alloys such as stainless iron.

Fig. 13 shows a typical tensile test curve for normalized medium carbon steel at 750 degrees Fahr. (400 degrees Cent.) and Fig. 14 shows a similar curve for heat treated stainless iron at the same temperature. In the first case the values of proportional limit and Johnson's limit are relatively close together but in the second case they are 27,000 and 80,000 pounds per square inch, respectively.

Fig. 15 and 16 show the same data for these two tests plotted

in such a way as to indicate deviation from the elastic curves instead of total elongation. Since the determination of proportional limit is based on the measurement of this deviation, these curves show how the chosen value is affected by the type of material and the degree of precision of strain measurement.

In Fig. 17 these two curves are plotted to the same scale for comparison. A change in the accuracy of measurement of total

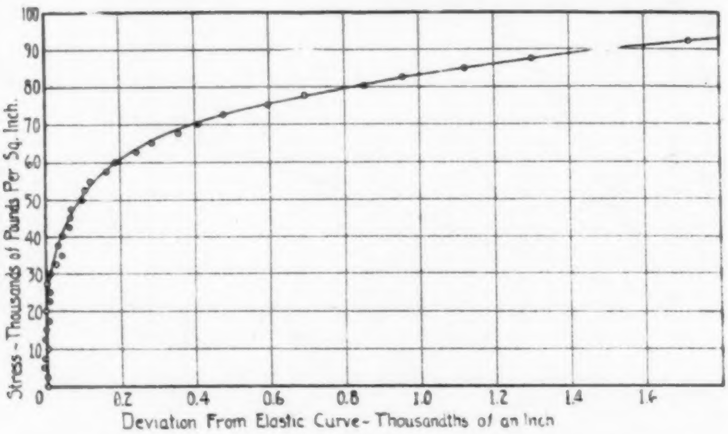


Fig. 16—Deviation from Proportionality—Same Data as Fig. 14.

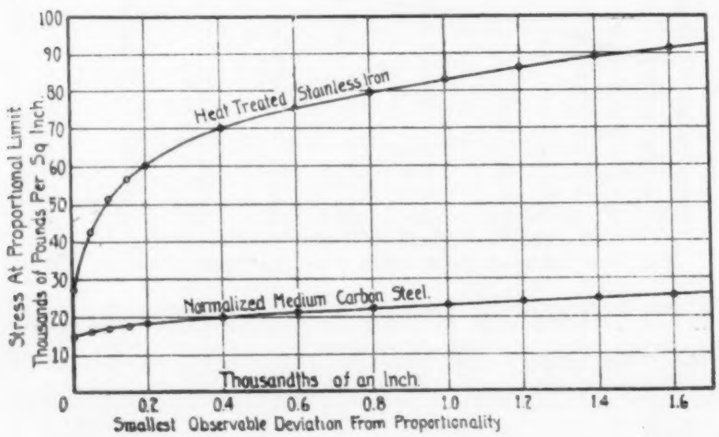


Fig. 17—Effect of Accuracy of Strain Measurement Upon the Determination of Proportional Limits.

elongation from 0.0002 inch to 0.000004 inch reduces the apparent value of proportional limit by about 17 per cent in the case of the medium carbon steel and over 50 per cent in the case of the stainless iron. These curves give a basis upon which the desirability of a change toward greater accuracy of strain measurement may be based.

(6) *Uniformity of test specimens.* When comparative tests are made, it is essential that every precaution be taken to ensure uniformity among the several test specimens. All of our steel

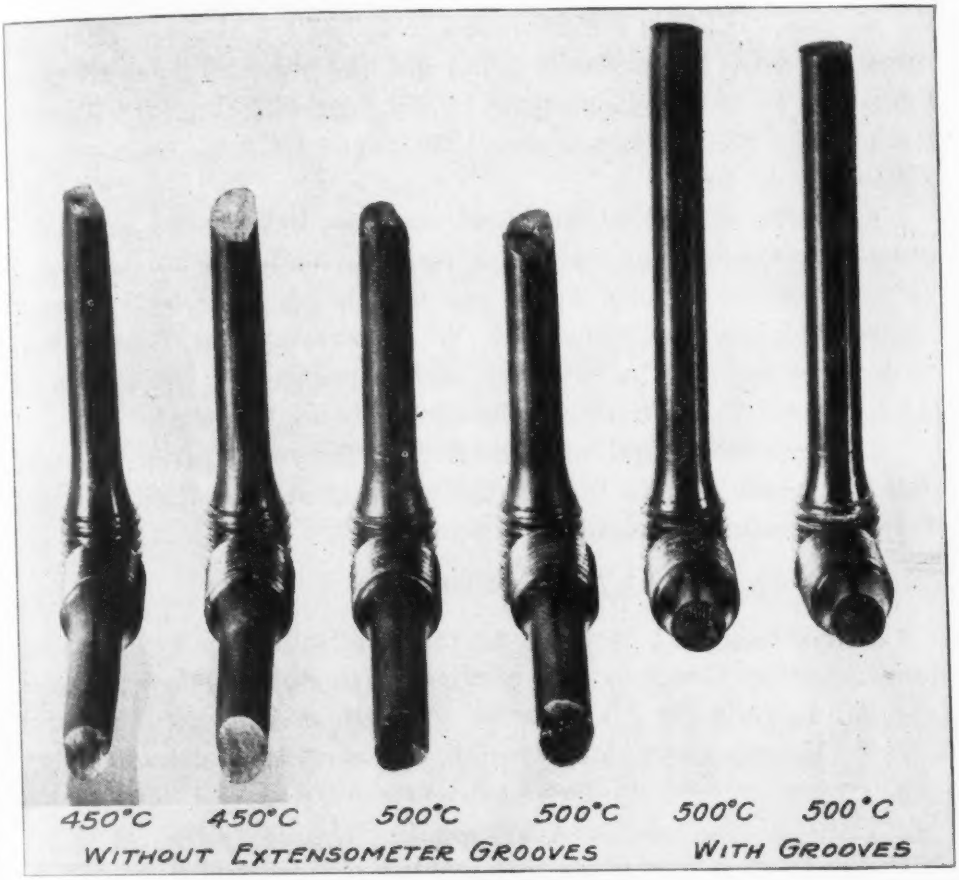


Fig. 18—Fractures of Monel Metal.

test specimens used for deterioration tests, (Tables I and II) are checked by Brinell and magnetic tests (18, 19) before their selection for use in tensile tests at elevated temperatures.

Summary and Conclusions

The data presented may be summarized as follows:

1. Annealed stainless iron of the grade examined is shown to possess good tensile properties up to 750 degrees Fahr. (400 degrees Cent.) without any evidence of brittleness. Between 750 and 930 degrees Fahr. (400 and 500 degrees Cent.) the strength decreases more rapidly and the ductility increases.

2. Hot-rolled Monel metal shows very good tensile properties

up to 750 degrees Fahr. (400 degrees Cent.) but at 930 degrees Fahr. (500 degrees Cent.) there is a considerable loss of ductility which is accentuated in the presence of a notch.

3. Charts are presented in which the main tensile properties of nine materials are compared in the entire range of temperatures studied. These charts bring out the value of heat treating stainless iron for application up to 750 degrees Fahr. (400 degrees Cent.). At 930 degrees Fahr. (500 degrees Cent.) some of this advantage is lost.

4. Tests show that annealed stainless iron of the grade examined does not deteriorate as a result of exposure to stress and temperature for periods up to one month. Similar tests of heat treated stainless iron show that the ultimate strength and ductility are not seriously affected by such exposure for periods up to 4½ months. Tests of this material are being repeated.

5. Details of equipment and procedure are given to stimulate discussion and to further the cause of standardized methods of tensile testing at elevated temperatures.

Acknowledgment

Acknowledgment is made to the Westinghouse Electric and Manufacturing Company for permission to publish these results: to J. M. Lessells for his valuable suggestions and criticism; and to T. F. Hengstenberg, laboratorian, for carrying out most of the tests.

Appendix I

Table I
Analysis and Heat Treatment of Steels

Material	Description	Chemical Composition—Per Cent C	Mn	P	S	Si	Ni	Cr	Cu
A	Medium Carbon Steel As Rolled	0.37	0.63	0.012	0.037	0.11	...	....	..
B	Medium Carbon Steel Bars, 2" in diam. Normalized at 875°C Soaked 3 hours at temperature; Air cooled	0.37	0.63	0.012	0.037	0.11	...	....	..
C	Medium Carbon Steel Bars 2" in diam. Quenched in water from 850°C; drawn at 600°C; Cooled in the furnace	0.37	0.63	0.012	0.037	0.11	...	....	..

D	5% Nickel Steel rolled bars, 1" in diam. Normalized at 815°C. Air Cooled	0.09	0.41	0.012	0.024	0.120	4.60	0.11	..
E	5% Nickel Steel Forged bars ⅞" x ⅞"; Oil quenched from 785°C; drawn at 620°C; Cooled from draw in oil ...	0.10	0.32	0.010	0.027	0.127	4.57	0.07	..
F	Stainless Iron. Forged Bars, ⅞" x ⅞"; Oil quenched from 955°C; drawn at 565°C; cooled from draw in oil	0.09	0.52	0.010	0.017	0.47	0.52	12.32	nil
G	Stainless Iron Rolled Bars 1" x 1"; Annealed at 790°C....	0.09	0.52	0.010	0.017	0.47	0.52	12.23	nil

Table II

Analysis and Heat Treatment of Nonferrous Metals

Material	Description	Chemical Composition, Per Cent										
		Cu	Sn	Fe	Mn	Zn	Pb	Al	Ni	C	S	Si
H	Cast Manganese Bronze—As Cast	58.4	0.79	0.68	0.38	39.0	0.031	0.71	.....	....	....	.....
K	Brass—Rolled and Drawn. Annealed at 565° C. for 30 Minutes	70.0	....	....	....	30.0	.....	....	.....	....	....	.....
L	Monel Metal Hot Rolled—As Received	28.71	....	1.94	1.94	....	.....	Nil	67.15	0.17	Nil	0.056

REFERENCES

(1) N. L. Mochel: Stainless Iron, TRANSACTIONS, American Society for Steel Treating, Vol. 10, September, 1926.

(2) T. D. Lynch, N. L. Mochel and P. G. McVetty: The Tensile Properties of Metals at High Temperatures; *Proceedings*, American Society Testing Materials, Part II, p. 5-52, 1925.

(3) N. B. Pilling and G. P. Halliwell: Softening of Hard-rolled Electrolytic Copper; *Proceedings*, American Society Testing Materials, Vol. 25, Part II, p. 97, 1925.

(4) The Deterioration of Turbine Blading: *Engineering*, May 4 and 11th, 1917.

(5) A Review of Turbine Troubles and Their Causes: North East Coast Institute of Engineers and Ship Builders, 1923.

(6) P. G. McVetty: Discussion of Paper by H. J. French on "Methods of Test in Relation to Flow in Steels at Various Temperatures"; *Proceedings*, American Society Testing Materials, Vol. 26, Part II, 1926.

(7) V. T. Malcolm: Methods of Testing at Various Temperatures and Their Limitations; Symposium on Effect of Temperature upon the Properties of Metals; *Transactions*, American Society of Mechanical Engineers, Vol. 46, p. 356, 1924. *Proceedings*, American Society Testing Materials, Vol. 24, Part II, p. 15, 1924.

(8) R. B. Wilhelm: Discussion, Symposium on Effect of Temperature upon the Properties of Metals; *Transactions*, American Society of Mechanical Engineers, Vol. 46, p. 489, 1924. *Proceedings*, American Society for Testing Materials, Vol. 24, Part II, p. 142, 1924.

(9) H. J. French: Discussion, Tensile Properties of Metals at High Temperatures by T. D. Lynch, N. L. Mochel and P. G. McVetty, *Proceedings*, American Society for Testing Materials, Vol. 25, Part II, p. 34, 1925.

(10) H. J. French: Methods of Test in Relation to Flow in Steels at various Temperatures; *Proceedings*, American Society for Testing Materials, Vol. 26, Part II, 1926.

(11) V. T. Malcolm: Discussion, Tensile Properties of Metals at High Temperatures by T. D. Lynch, N. L. Mochel, and P. G. McVetty. *Proceedings*, American Society for Testing Materials, Vol. 25, Part II, p. 43, 1925.

(12) L. W. Spring and J. Kanter: Accuracy in High-temperature Testing of Materials; *Power*, Vol. 62, #9, p. 325, 1925.

(13) Report of Committee E-1, *Proceedings*, American Society for Testing Materials, Vol. 25, Part I, p. 409, 1925.

(14) R. R. Moore: Discussion on Methods of Testing; *Proceedings*, American Society for Testing Materials, Vol. 24, Part I, p. 732, 1924.

(15) W. A. Cowan: Discussion on Report of Committee B-2, *Proceedings*, American Society for Testing Materials, Vol. 24, Part I, p. 275, 1924.

(16) P. G. McVetty: Discussion of "A New Type of Mirror Extensometer" by M. F. Sayre; *Proceedings*, American Society for Testing Materials, Vol. 26, Part II, 1926.

(17) D. J. McAdam, Jr.: Fatigue of Corrosion Resistant Steels; *Proceedings*, American Society for Testing Materials, Vol. 24, Part II, p. 273, 1924.

(18) Topical Discussion on Magnetic Analysis; *Proceedings*, American Society for Testing Materials, Vol. 19, Part II, p. 5, 1919.

(19) Thomas Spooner: The Magnetic Analysis of High-Speed Steel; Report of Committee A-8, *Proceedings*, American Society for Testing Materials, Vol. 26, Part I, 1926.

(20) G. Welter, "Elastizität und Festigkeit von Spezialstählen bei Hohen Temperaturen," Forschungsarbeitan aus dem Gebiete des Ingenieurwesens, No. 230.

The Authors

P. G. McVetty has been connected with the research department of the Westinghouse Electric and Manufacturing Co., since 1924. After he received his degree of Mechanical Engineer from Cornell University in 1913, he was instructor in experimental engineering and engineering research at Cornell until his enlistment in the Signal Corps of the U. S. army. He was later commissioned a first lieutenant and served with the army schools of military aeronautics. After the armistice, he was in charge of research for the Leather Belting Exchange Corporation and later an assistant superintendent at the South Side works of the Jones

and Laughlin Steel Corporation, giving special attention to open hearth furnace research and development. His birth place is Buffalo, New York.

P. G. McVETTY

N. L. MOCHEL

N. L. MOCHEL began his career in 1912 in the Inspection Department of the Westinghouse Machine Company and continued in this position after the merger with the Westinghouse Electric and Manufacturing Company. In 1920 he was given the position of metallurgical engineer at the new South Philadelphia Works. He served with the Engineer Corps of the United States army in France. He was born, raised and educated in Pittsburgh.

Written Discusion:—By T. McLean Jasper, A. O. Smith Corporation, Milwaukee.

The writer wishes to compliment the authors on the experiments reported in this paper and also wishes to respond to the expression of their sincere desire in stimulating the discussion on test results and test methods. Undoubtedly a very considerable amount of painstaking work has been done and this should receive the recognition it deserves. Unfortunately the methods adopted in obtaining the results are not as clear as might be desired and therefore difficulty might be encountered in discussing the methods of testing adopted by the authors in this paper.

The writer is particularly interested in the correct values of the elastic constants for steel and other ferrous metals at elevated temperatures. He has had to recognize that varying values of the modulus of elasticity will be obtained at particular elevated temperatures for any one material which will depend largely on the rate at which the load is applied. No degree of sensitivity of strain or of load measurements will overcome this difficulty. The

writer therefore believes that the author's results for the modulus of elasticity at 500 degrees Cent., are considerably too high. The curve showing the value of the modulus of elasticity for five per cent nickel steel normalized (Fig. 7) seems unusual. The writer does not believe that the value of the modulus of elasticity ever changes to a higher value for any positive increment of temperature within the range of temperatures investigated by the authors. These observations are based on experimental data, on considerations of the "kinetic theory" of solids and on consideration of the increase of atomic mobility with increase of temperature.

The writer would therefore respectfully inquire how the values of the modulus of elasticity were obtained especially the rate at which the loads were applied at various elevated temperatures.

The application of the value of the modulus of elasticity and modulus of rigidity to design calculations bears directly on the operation of springs and other devices which may be used at elevated temperatures.

The writer would like to draw attention to some very excellent results of tests on metals at elevated temperatures by Prof. F. C. Lea, Sheffield University, which are published in quite a few papers during recent years and which might properly form part of the author's bibliography.

H. W. GRAHAM: I should like to ask Mr. McVetty if he has noticed any increase in tensile strength at slightly elevated temperatures. Results of older experiments published some years ago almost always indicated an increase in tensile strength at an elevated temperature. I have had some opportunity to witness rather crude tests that also have supported this view. I may have missed the point in the paper but it seems to me the charts indicate a rather constant decrease in tensile strength and proportional limit as the temperatures were increased. I think one would expect that with the ductility shown there would be some increase in tensile strength.

I have seen some experiments made with somewhat higher temperatures than were dealt with in this paper, particularly up above 1400 or 1500 degrees Fahr., (760 or 815 degrees Cent.), in an effort to study the physical properties of steel at forging temperatures. And there, in ranges that went from 1200 to about 1600 degrees Fahr., (650 to 870 degrees Cent.) we found some tests that were very much like the monel metal tests of which Mr. McVetty speaks. There seem to be sudden changes of ductility in the temperature areas about the transformation point, and some of them were extremely important.

We made some tests on ingot iron in an effort to study the effects of a minimum of carbon, using that as one reference point on the extreme end of the carbon curve, and it was found that with extreme temperatures, they would break. Some effort was made to apply this to the rolling and forging problem, but with no great success. There might be, however, some interesting work carried out to associate the type of fractures obtained with the critical points and the structure of the material at those temperatures.

R. L. TEMPLIN: Mr. Chairman, we have done quite a little work on the testing of aluminum at high temperatures. The paper covering that work is now in the process of preparation and perhaps therefore it is a little

premature to say anything about the actual results which we obtained but a few points in connection with the technique of testing used by the authors compared to those we have used might be mentioned.

One thing that impresses me has to do with the form of test specimen used. We have been averse to the use of a test specimen with threaded ends of the design shown by the authors of this paper because our tests indicated that at the higher temperatures, in what is called the "hot-short" range, where the material becomes brittle, it is extremely difficult to get satisfactory breaks using such a specimen. We use a slightly different form of threaded end test piece which appears to give us much more satisfactory results.

Another point, if I correctly understood the drawing shown, the thermocouples used by the authors in measuring the temperature are just put through the side of the furnace so as to be adjacent to or nearly touch the specimen. I am wondering whether they have found that such a scheme gives satisfactory temperature values for the test specimen. We did not find it so for our work.

We have not used the mirror-type of extensometer as described by the authors in this paper. Apparently we are fortunate in our work in that the material which we test has a low modulus so that we can get very satisfactory results without such precise apparatus. We now have on order, however, such apparatus.

We have found it very necessary when using extension bars reaching into the furnace, to compensate for temperature variations as much as possible, partly by having all the bars the same length. An appreciable difference in the length of the bars used is shown by the authors.

As I was unable to secure a preprint of the paper, I don't know whether or not some other points that occurred to me have been covered therein. I would be interested to know what variations of temperature were encountered in the furnaces which they used, about how closely they think the temperatures were controlled and about how closely the mechanical property values of an individual test bar check with similar values of other specimens at the same temperature.

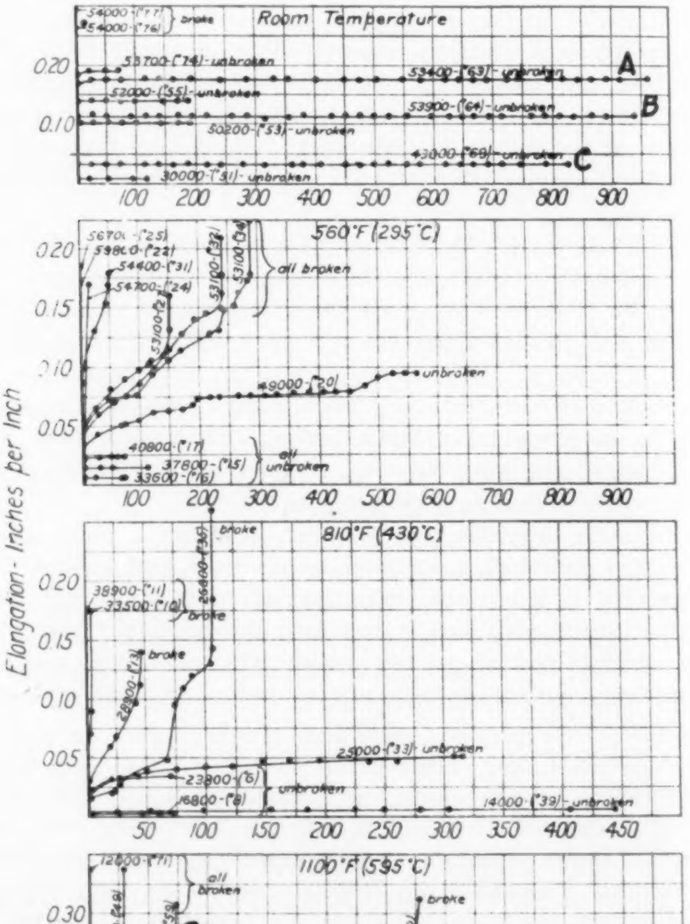
We have obtained very satisfactory modulus values for our different alloys together with the other mechanical properties indicated by the authors, but so far our program has not included the so-called long time temperature tests, although it is our intention to include such tests at some future date.

H. J. French: Unfortunately, I did not know that there was a preprint of this paper until I came into the room and therefore I have not had time to study the described results in detail, but to those of us who have followed, for a number of years, the testing of metals at high temperatures, this contribution of Messrs. McVetty and Mochel seems to be of very great value and interest. I would like to refer for just one moment to the question of long-time or so-called "creep" tests, and perhaps carry the conception given by Mr. McVetty a little bit further, in that I want to show you the relation between "creep" and temperature.

If we make "creep" tests and plot the creep as the ordinate and the time of application of the load as abscissa, we find at ordinary temperatures that

if the load is sufficiently high the specimen elongates for a measurable period of time. This elongation is followed by what appears to be, with available measuring devices, cessation of flow as shown by curves A and B, Fig. 1. If the load is somewhat lower a similar curve is obtained, but the cessation of flow occurs at a lower total elongation as in curve C, Fig. 1. With still lower loads this "initial creep" becomes smaller until the load approximates the proportional limit of ordinary tension tests when the creep is practically zero or at least very small.

Fig. 1



The fact that the initial creep ceases for all practical purposes after a measurable time of application of a large load may be ascribed to "strain hardening" of the steel. If, now, instead of making "creep" tests at ordinary

temperatures, we carry out similar experiments at fairly high temperatures, for example, at 1100 degrees Fahr., we get a different set of curves. We find that instead of this appreciable strain hardening effect, when we apply a high load, a specimen of ordinary low carbon steel will stretch continuously and finally break as shown by curve D, Fig. 1. If the applied load is somewhat less, we find that we may get a curve like E, Fig. 1, if still lower, a curve like F, and finally, a curve in which the rate of ''creep'' is very small, as in G.

If we study such a set of curves, as are shown in Fig. 1 for low carbon steel at various temperatures, a composite diagram can be prepared which gives

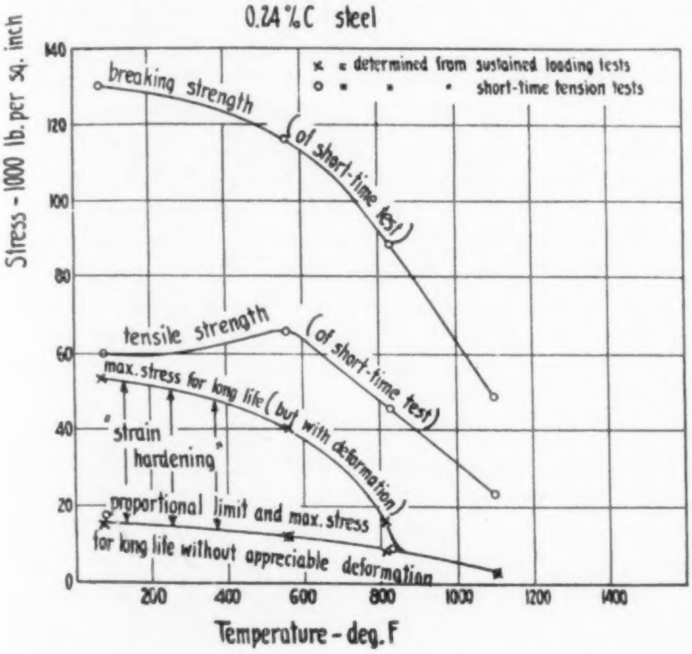


Fig. 2—Comparison of Results Obtained in Flow Tests and the Customary Short-time Tension Tests at Various Temperatures for a 0.24 per cent Carbon Steel.

considerable useful information. One such diagram is shown in Fig. 2, and you will note that in this is shown the effect of temperature on the tensile strength and proportional limit of the customary short time tests as well as the loads permitting long life both with and without appreciable deformation. I shall not go deeply into the various features but want to point out that the proportional limit of the short time tension test approximates the maximum load permitting long life with freedom from appreciable deformation at corresponding temperatures. This has recently been confirmed with other steels. Note also that at only moderately high temperatures the steel will maintain higher loads for long periods on account of ''strain hardening'' but will at first deform.

It is rather interesting to note that from our own tests we find that the limit of strain hardening in ordinary boiler steel is somewhere in the neighborhood of 800 or 850 degrees Fahr.; that for the high chromium ''stain resisting'' steel is at somewhat higher temperatures, and we have tested one or two

ferrous alloys in which the range of strain hardening is extended to appreciably higher temperatures.

There is one point I would like to mention at this time, although I do not believe it is of practical importance; nevertheless, it is, at least, of theoretical interest. Mr. McVetty has mentioned the importance of the accuracy and sensitivity of test equipment as affecting the observed values of "load carrying ability" and proportional limits which may be secured in any test. Is it not conceivable that when we are above the strain hardening temperature range of any particular steel, that if we used some sufficiently sensitive measuring device, we would find that we only had a zero rate of creep when the load was at or very close to zero? As I say, that is not of practical importance at the moment, but it is of theoretical interest; whether "creep" is a few millionths of an inch per month or a few hundred thousandths of an inch per month, the steel has a useful load carrying ability. The value of the allowable load is, as has previously been pointed out by Mr. McVetty and others, largely a function of the amount of deformation that you can stand in your structure.

The described conception of "creep" and its relation to the ordinary tensile test at corresponding temperatures is a subject which is of very great practical interest. Perhaps some of you are already aware of the fact that the American Society for Testing Materials and the American Society of Mechanical Engineers, about a year and a half or two years ago, formed a special Joint Research Committee to take up the question of the methods of testing and application of metals at high temperatures, and that in their program of tests there are included a variety of metals which will be studied under both long-time and short-time tests. Long-time tests are exceedingly expensive to carry out, and, from an inspection standpoint, if from no other, it would seem highly desirable to secure information from some quick test, which, if it does not give quantitative data, will at least give a qualitative indication of what the load carrying ability of materials is at different temperatures.

Mr. McVetty and his co-workers are to be congratulated upon their very excellent work as recorded in their paper.

AUTHORS' CLOSURE—P. G. MCVETTY: Mr. Jasper has brought up a very interesting point in connection with the meaning of the term "modulus of elasticity" at elevated temperatures. It is commonly considered as a property determined by the slope of the straight portion of the stress-strain curve in the tensile test. This method was used in obtaining the data here reported, the average rate of loading being approximately 1500 pounds per square inch per minute. We try to maintain this rate in all of our tests so that they will be comparable one with another. Following Mr. Jasper's suggestion that the modulus of elasticity of a material is a variable depending upon the rate of stress application, it is evident that various values must be used, depending upon the type of service. On this basis, the values here given will be somewhat low for use in vibration formulae and are therefore on the safe side. On the same basis they will be high for use in determining the deformation to be expected from a certain stress applied slowly or sustained over a long period of time. For this reason, we use the long-time tensile test at

elevated temperatures to determine the deformation resulting from sustained tension loading under working conditions of stress and temperature. Our experience indicates that extreme care must be used in substituting values of modulus of elasticity in design formulae involving stress-strain relations at elevated temperatures.

In reference to the modulus curve for normalized five per cent nickel steel we agree that it is abnormal, but we have been unable to discover any error in the test data. Our duplicate tests check closely as shown in results previously reported (2) and it is significant that similar results have been reported by Welter (20). An account of the sensitivity of strain measurement to very slight changes in temperature, it is quite possible that this abnormal variation may be due to slight temperature changes during the progress of the tensile test.

The authors are familiar with the various papers published by Prof. F. C. Lea, but it was their intention to refer only to such papers as appeared pertinent to the subject matter. The references given are not intended to represent a selected bibliography.

Referring to Mr. Graham's question, I would say that most steels show a higher ultimate strength in the so-called "blue heat range" at about 525 degrees Fahr. (275 degrees Cent.) than they do at normal temperature. This is shown in Fig. 6, which indicates that stainless iron (materials F and G) may be an exception to the general rule. It appears also from Fig. 8 that the increased strength of ordinary carbon steels at this temperature is accompanied by a decrease in ductility but we have no evidence that the decrease in ductility of monel metal above 750 degrees Fahr. (400 degrees Cent.) is accompanied by an increase in ultimate strength. To settle this point, additional tests have been made at 840 and 930 degrees Fahr. (450 and 500 degrees Cent.) without cutting grooves for the extensometer at the ends of the gage length. The results of these tests have been included in Fig. 4 and the type of fractures obtained are shown in Fig. 18. These tests prove that the ultimate strength of monel metal does not increase with the decreasing ductility above 750 degrees Fahr. (400 degrees Cent.). The character of the fractures shows also the importance of avoiding tool marks or other surface imperfections when using monel metal in this temperature range.

It would be interesting to study physical properties of materials at forging temperatures as suggested by Mr. Graham but we are at present more interested in the application of materials to service conditions and the tests made up to date are well below the transformation points of the various materials.

In reference to Mr. Templin's objection to the use of a test piece with threaded ends, I can only say that we have not encountered the difficulty he mentions. In my experience a break at one end of the gage length is extremely rare and most of our tests break within the middle third of the gage length. This difficulty seems to depend upon the properties of the particular material tested, and it appears that we have been fortunate in escaping tests of materials of this character.

In reference to our method of measuring temperature, I agree that it may

not be entirely satisfactory. Objections may be raised to any of the methods which have been proposed and we are still working on this problem. Until we find a better method, it seems best to continue with the one we have used for over three years, so that our results will be comparable. Our thermocouple bead is made small so that the point of separation of the two metals forming the hot junction is kept as close as possible to the surface of the test specimen. The couple is held in position at the center of the gage length by means of a spring.

All of our furnaces are calibrated using a standard test specimen with thermocouples bedded in radial holes 1/16 inch deep at the top, center and bottom of the gage length. This test specimen is assembled in the testing machine and a fourth thermocouple located according to our regular procedure. The furnace is heated and the temperature maintained constant for at least five hours to ensure temperature equilibrium. The following readings from one calibration are representative:

Couples bedded in test specimen:	
Top	420.5°C
Center	430 °C
Bottom	423.5°C
Average	424.7°C
Couple in contact with test specimen:	
Center	425°C

These data indicate a close agreement between our method and the average of three couples bedded in holes in the test specimen at the top, center and bottom of the gage length.

The total variation over the gage length is about 10 degrees Cent. (18 degrees Fahr.). This variation is somewhat greater in the tests at 500 degrees Cent. (930 degrees Fahr.) and less in the tests at lower temperatures, amounting to about ± 1.25 per cent of the desired temperature.

Our type of extensometer would require temperature compensation if any temperature changes occurred during the test. It is to avoid this difficulty that we use at least five hours in heating the test specimen prior to the test to ensure temperature equilibrium.

We do not use a temperature control in our short-time tests but adjust the furnace current to hold the desired temperature. A variable-voltage transformer enables us to vary the furnace current in equal steps of approximately 0.05 amperes. The line voltage is closely controlled by an induction regulator. If our readings show a temperature change below the yield point, it is necessary to discard the values of proportional limit and modulus of elasticity for that particular test.

In our long-time tests, the maximum variation in temperature of the test specimen is usually within 5 degrees Cent. (9 degrees Fahr.) at 400 degrees Cent. (750 degrees Fahr.). Readings of length must be averaged over the entire temperature cycle and these averages lie within one degree Cent. (2 degrees Fahr.) of the curve through the points. (6).

In reference to variation among test bars and how closely any one bar

(Continued on Page 169)

TOOL STEEL FAILURES—THEIR CAUSES AND CURES

By Frank B. Lounsberry

Abstract

The author of this paper sets forth the various things which assist a tool maker in the selection of tool steels and in the attainment of the greatest possible service from the manufactured tools. The statements contained in this paper are based on data obtained in the investigation of from 400 to 500 complaints per year, extending over a period of years. These investigations show that 55 per cent of the complaints are due to faults at the mill and of these about one-half are due to faulty inspection. The author is of the opinion that greater care should be given to inspection and that closer control in the melting operations will eliminate much of the trouble. He is also of the opinion that physical and chemical specifications are of inestimable value when purchasing tool steels and that about 60 per cent of the larger users are buying steel according to their specifications and upon acceptance assuming all further responsibility. Better control of the melting operations will result in better steel and the electric furnace is a valuable aid in this respect.

Accurate temperature control is imperative. A fine furnace, an accurate pyrometer and an intelligent operator are the principal factors in producing good tool steel. Cooperation between the manufacturer and the tool maker results in mutual benefit. These are some of the things which, in the author's opinion, will result in eliminating tool steel failures.

THE practical side of metallurgy which deals with its manufacture and its subsequent use is one that always can be discussed to advantage, the results of which can be checked up and confirmed at any time by experimentation and experience. It is in this connection that we desire to bring to attention certain things which may enable us to better select tool steels and after selection obtain more satisfactory results from them. Despite improvements in equipment and advances which have been made in heat treatment of all steels, it is rarely the case that tool steel users obtain the maximum service possible from the steels they purchase.

A paper presented before the Philadelphia Chapter of the Society. The author, Frank B. Lounsberry, is vice-president of the Atlas Steel Corporation, Dunkirk, N. Y.

During the course of a year's regular laboratory routine in the mill with which the author is associated there are normally 400 to 500 complaints to handle. These complaints are all recorded, carefully analyzed and classified. This accumulation after many years gives a fairly accurate estimate of not only mill faults, but also those most frequently encountered by the user. We have long made it a practice that when a complaint is made by a customer to immediately investigate the matter regardless of whether the complaint comes from a large or small user. If the complaint is made to the mill we either send someone directly, or refer it back to the district in which it originated, for attention. Frequently by prompt action the district salesman or manager can correct the difficulty immediately and no further attention by the mill is required. More often, however, in order to arrive at a clear and definite understanding of what the difficulty is, the salesman secures samples of the product complained of and sends it to the mill with complete data for a laboratory report. These are the type of complaints with which this paper deals.

The complaint as received is given a number and goes to the laboratory for complete physical and chemical examination. This involves chemical analysis, hardness tests, fracture tests, micrographic and macrographic examination, as well as specific tests, depending upon the nature of the case. A complete report is prepared and submitted for consideration. Inasmuch as most complaints are apt to involve adjustment of some sort it is necessary first to impartially decide whether or not the complaint is justified, and whether the difficulty is due to the mill or to the customer's handling. This decision is sometimes in error, but always it is honest and based on our experience and the facts which the laboratory is able to establish. To do otherwise would be a short-sighted policy and an utter waste of time and effort. For only insofar as we are able to intelligently interpret the facts and to correct or improve the conditions found can we hope to improve our situation, or that of the customer. This forms the basis for the first general classification—MILL'S FAULT—CUSTOMER'S FAULT.

We now come to the more specific matter and one which will be of greater interest. What has preceeded is more by way of introductory and to give an idea as to how our data is arrived at. Over a period of years we find that of all the complaints re-

corded for whatsoever reason; in (55%) of the cases the mill is at fault; and in (32%) of the cases the cause lies with the user. The balance, or (13%) are special. This is not the answer that some of you expected, and undoubtedly is quite a shock to steel men, but you at least will credit us with being honest even though it seems to show the mill up to a disadvantage.

In order not to create a wrong impression as to the amounts of steel involved may we say that the total weight complained of per year is only about 100,000 to 120,000 pounds having a value of $20,000.00 to $25,000.00, of which the majority is recovered or salvaged in one way or another.

Since in the greater number of cases the steel mill is at fault we will analyze these first. Of the (55%) listed as MILL'S FAULT, (24%) falls in the class headed by inspectors errors, such as size and shape, pipe, seams, laps, bark or decarburization, pits, marks and other surface defects. ($17\frac{1}{2}$%) under internal conditions such as internal seams, secondary pipe, slag or oxide inclusions, segregation of all kinds and microstructure. (8%) under annealing or heat treatment—this includes wrong hardness due to annealing resulting in poor machineability, or hardening losses due to poor annealing, also improper heat treatment on the part of the mill. (5%) due to wrong analysis or grade—this includes cases where the wrong grade has been applied on our part, or through an error in manufacturing a wrong analysis has been shipped, such as carbon for high speed, or oil hardening for water hardening. The (13%) which is listed as "special" include cases of wrong size or grade ordered, due to clerical errors, etc. and cases where responsibility cannot be definitely determined and fixed.

Of the (32%) listed as CUSTOMER'S FAULT, the majority fall under the heading of heat treatment, amounting to ($22\frac{1}{2}$%). (3%) is wrong application or analysis for the use intended. ($2\frac{1}{2}$%) due to forging or machining strains. (1%) due to faulty design or mechanical trouble. (1%) due to improper grinding, resulting in cracks and the balance to unclassified reasons too isolated to warrant grouping.

From the foregoing it is quite evident that what is required most, from the steel makers standpoint, is greater care in inspection and closer control in his melting operations. Despite the fact

that approximately one quarter of all employees in a tool steel plant are engaged in some sort of inspection or control work, still (25%) of all tool steel failures are due to the things they miss. As stated above most defects of this kind, pipes, decarburization, seams, etc. are quite evident and should be easily caught. Many large consumers now have definite specifications covering such items as size tolerance, seam depth, depth of decarburization, pits and other surface defects. When intelligently written these specifications are a great help to the steel manufacturer and eliminate 75% of the possibilities of rejection from these causes. We cannot too strongly recommend the value of chemical and physical specifications when the amount of steel purchased warrants, and the consumer has laboratory facilities for checking and seeing that his specifications are being met.

Where ten years ago there were practically no specifications covering the purchase of tool steels, today 60% of the large consumers buy according to their own specification and accept all responsibility for the steel once it has passed their inspection and approval. General specifications to cover all uses are not possible, and in order to obtain best results for any particular requirements, the buyer should consult freely with the steel manufacturer and let him assist in the proper drafting of the requirements.

There is still much to be accomplished by the steel maker in his methods of inspection and his control of operations. The problem of proper heat control from the melting house down through the hammer and mill departments is ever present. It is only when the product arrives at the annealing department that there is any real and accurate temperature control. A certain amount of temperature control is maintained in all of the above mentioned departments, including permanent pyrometer installations on the finishing mill furnaces. Nevertheless there are so many other factors entering into the heating problem that results are bound to show considerable variation. As an example—the variation of 75 to 100 degrees in the finishing temperature on high speed steel is sufficient to throw some bars out of size tolerance and possibly result in seams or cracks if too cold, and burned or cracked edges if too hot. Again on small sizes a soaking from 15 to 20 minutes overtime in an oxidizing furnace atmosphere will cause excessive bark and scale, resulting in defective material.

A second large consideration from the steel maker's standpoint is more control in the melting operations. It is a common saying in the steel mill that when trouble shows up anywhere it usually is traced back to the melting house. This of course is not literally true, but is true to an extent that if every ingot turned out were 100 per cent perfect, the majority of the steel makers perplexing problems would be removed. The subject is so large and involved that it will be impossible to go into it in detail, but many of the illustrations which accompany this paper show certain defects which are directly the result of improper melting and subsequent operations. The electric melting furnace has been a big aid to the tool steel manufacturer in helping him to obtain better control over his operations, both from a chemical and a thermal standpoint.

Regarding tool makers troubles, or as we term it CUSTOMER'S FAULT, the greatest variable is that of heat treatment. Improper heat treatment,—how often we hear about it, how much it is preached against, yet it accounts for (70%) of all troubles the tool maker has in his own shop. The failures due to faulty design, machining difficulties, wrong application, etc. can almost be ignored; as can also grinding and its subsequent losses. Under this factor of heat treatment, perhaps the main causes of trouble may be summarized as due to four principal errors:

1. Rapid heating
2. Over heating
3. Furnace atmosphere conditions
4. Improper tempering.

RAPID HEATING—This practice usually results in non-uniform and abnormal strains resulting in cracks, deformation and uneven hardening. OVERHEATING—Usually results in burned edges and points, enlarged grain size with resultant brittleness and cracking, and abnormal changes in size and shape. Lack of control over FURNACE ATMOSPHERIC CONDITIONS—usually results in decarburization and soft tools; blistered, burned and scaly surfaces resulting in loss of size and shape. IMPROPER TEMPERING—This error especially in high speed steel, accounts for more failures than any of the others. Insufficient and improper tempering results in cracking, brittleness, poor cutting ability, deformation and indirectly for many other troubles. One expression which may classify heat treatment difficulties is "lack of control."

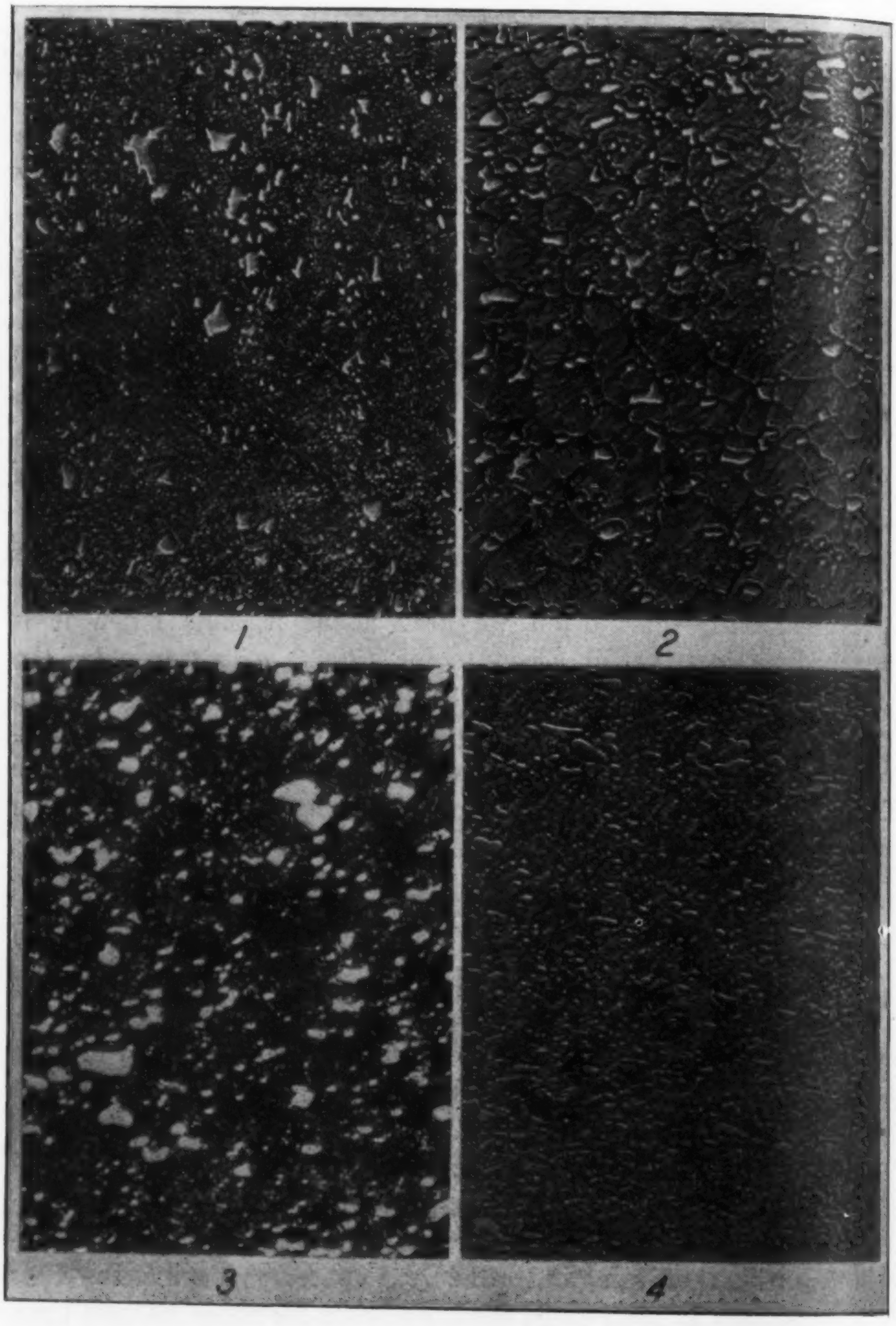


Fig. 1—High Speed Steel Properly Annealed—Showing a Uniform Carbide Distribution Brinell Hardness of 212-228. Fig. 2—High Speed Steel Properly Hardened at 2350 degrees Fahr. in Oil—not Tempered. This Shows the Typical Polyhedral Structure of Austenite with Well-defined Boundaries and Uniformly Distributed Carbides. Rockwell Hardness about 62-64 C. Fig. 3—High Speed Steel Properly Hardened and Tempered at 2350 degrees Fahr. Oil—1100 degrees Fahr. for 2 Hours. This Shows Practically Complete Conversion of Austenite to Martensite, Complete Disappearance of Grain Boundaries and a State of Maximum Hardness and Cutting Ability. Hardness about 64-65 C. Fig. 4—High Speed Steel Underheating—Carbides not in Solution and Austenite Incompletely Formed—Such a Structure Will Show as Quenched Approximately Rockwell 58-60 C Hardness—but will not Stand a High Temper or Show Good Cutting Efficiency.

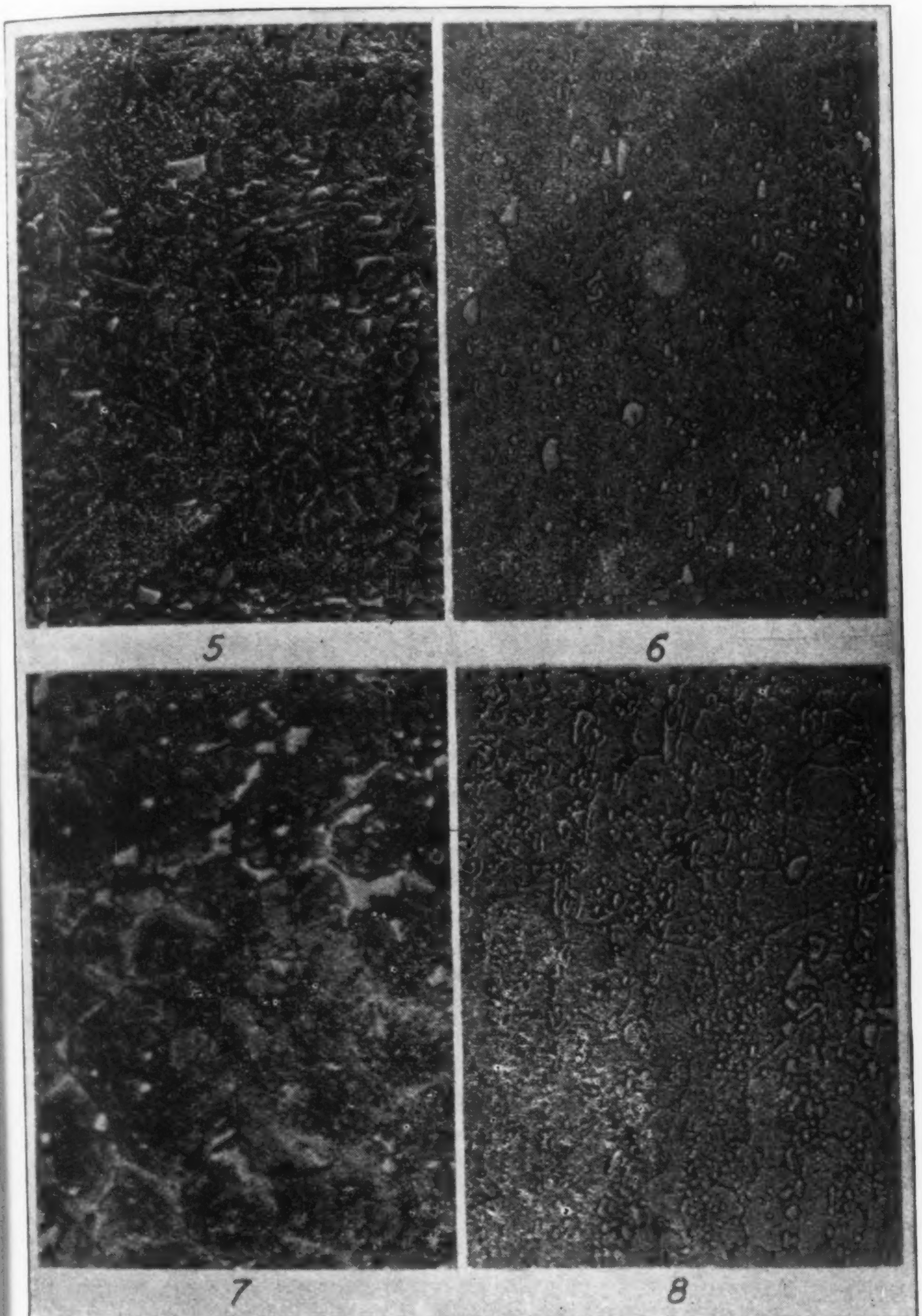


Fig. 5—High Speed Steel—Example of Mild Overheating and Insufficient Temper. Austenite and Large Martensitic Needles. Taken from an End-Mill which Failed by Breaking Out. This Type of Structure is Very Brittle and Liable to Grinding Cracks. Fig. 6—High Speed Steel—Considerably Overheated and Soaking too Long at Temperature with Little or no Temper. 500 x. Taken from a Cut-Off Tool that Failed in Service After a Short Time. Note the Large Grains of Austenite and Few Remaining Undissolved Carbides. This Represents a Very Brittle Type of Structure—Treatment Approximately 2400 degrees Fahr.—Oil and 500 degrees Fahr. Temper. Fig. 7—High Speed Steel—Badly Overheated in Hardening—Slight Fusion Started. 500 x. Note Absence of Carbides. Dark Areas Indicate where Fusion has Started to Take Place. Extremely Brittle. Taken from the Point of a Twist Drill that Failed in Test. Fig. 8—High Speed Steel—Example of Insufficient Tempering—Taken from an End-Mill that Broke in Service. Similar to Fig. 2.

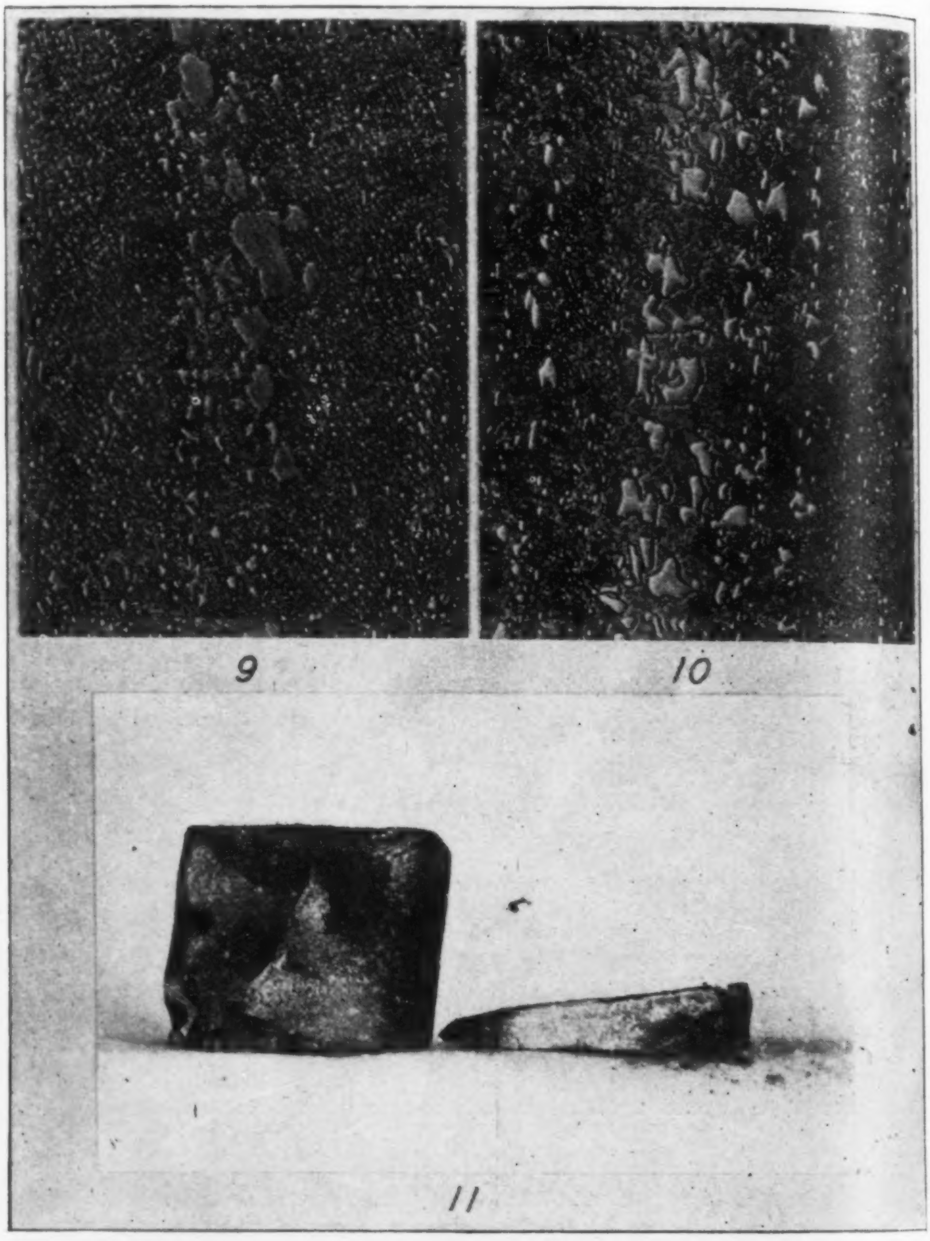


Fig. 9—High Speed Steel—Carbide Segregation in Annealed Bar. 500 x. Size of Bar Approximately 2" x 1". This is the Result of a Large Cellular Structure in the Cast Ingot which has not been Entirely Broken up by Subsequent Working. Always Dangerous—Causing Hardening Cracks, Crumbling of Cutting Edges and Brittle Areas in General. Amount of Carbide Segregation is Dependent Upon Amount of Work Put Upon Ingot and is Almost Directly Proportional to Bar Size. Fig. 10—High Speed Steel—Carbide Segregation in a Tap Made from 1⅜ Inch Round Bar. Shows Retained Austenite Surrounding Carbide Segregated Area. Remainder of Structure Satisfactory. 500 x. Fig. 11—Fractures Representative of Fig. 6. Small Fracture from Failed File Cutter—Very Brittle. Large Fracture from Boring Tool that Broke in Service. Both of These Fractures Show What is Ordinarily Termed a Flaky Hardened Fracture. Usually Due to One of Two Causes. Repeated Hardening Without Adequate Annealing Between, or Excessive Soaking at Hardening Heat. Both Result in an Enlarged Grain Structure (Fig. 6) and a Very Brittle Condition.

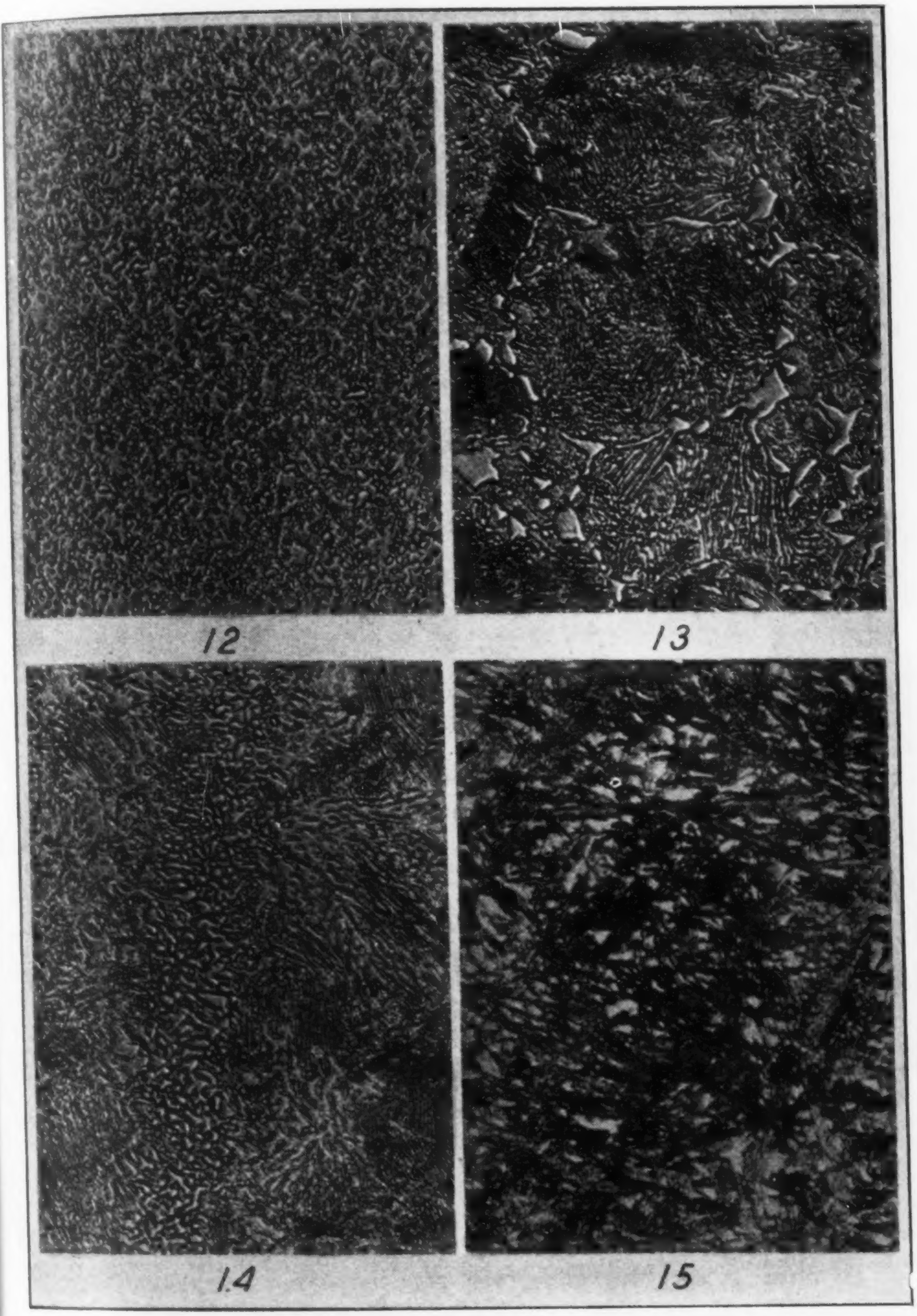


Fig. 12—Annealed Structure of 1.00 per cent Carbon Steel Showing Completely Spheroidized Condition. 500 x. Brinell about 160-170. Fig. 13—Poorly Annealed 1.20 per cent Carbon Steel Showing Lamellar Pearlite and Traces of Grain Boundary Cementite. 500 x. Brinell Approximately 228. Fig. 14—Poorly Annealed Oil-hardening Non-deforming Steel Showing Lamellar Pearlite and Carbide Segregation. 500 x. Fig. 15—Structure Shown by Fig. 20—Die of Oil-hardening Non-deforming Steel. 100 x. Showing Large Martensitic Needles.

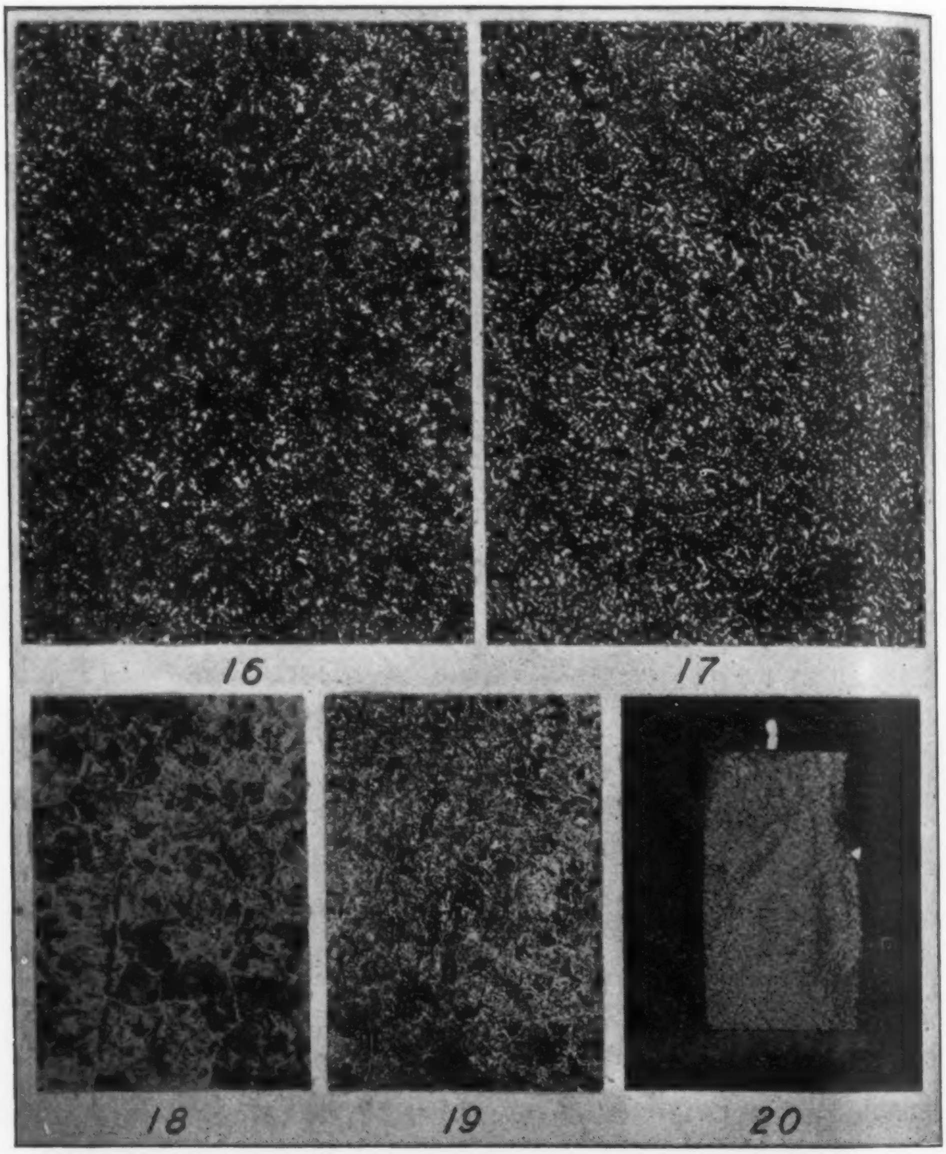


Fig. 16—Properly Hardened Structure Shown by Oil-hardening Non-deforming Steel. 500 x. Hardened 1400 degrees Fahr. Tempered 375 degrees Fahr. Fig. 17—Properly Hardened Structure of Carbon Steel. 500 x. Approximately 1.00 per cent Carbon. Fig. 18—Normal Carbon Steel—100 x. Photomicrograph of Case of 0.85 per cent Carbon Steel Carburized 3 hours at 1800 degrees Fahr. Ehn Test. Fig. 19—Abnormal Carbon Steel, 100x. Photomicrograph of Case of 0.85 per cent Carbon Steel Carburized 3 Hours—1800 degrees Fahr. Ehn Test. Fig. 20—Fracture of Die of Oil-hardening Non-deforming Steel which Broke in Service—Showed Overheated Condition.

In closing may we point out that this paper has covered in some detail, the principal causes of tool steel failures, also some suggested cures for individual types of failure emphasizing two factors which will tend to eliminate most difficulties; namely—

1. Greater Control
2. Co-operation.

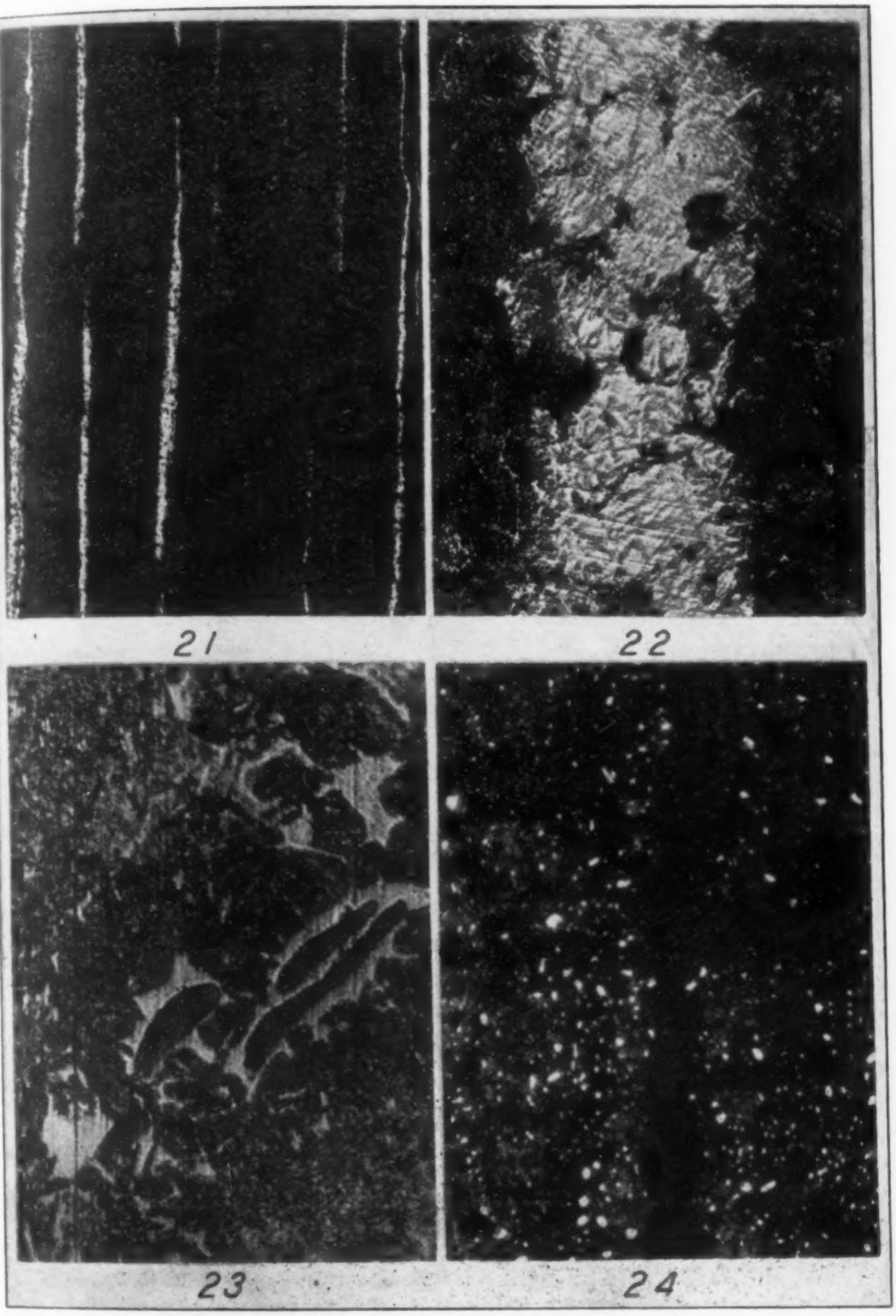


Fig. 21—Banded Structure Shown by Chromium-molybdenum Bearing Steel, not Annealed—Size $1\frac{7}{16}$ Inch Round. Approximately 50 x. Bands are Ferrite Segregation. Fig. 22—Ferrite Segregation in Chromium-molybdenum Bearing Steel. 500 x. Photomicrograph of One of Bands Shown in Fig. 21. Fig. 23—Slag Inclusions Surrounded by Ferrite. Taken from Tensile Test Piece from Forging of Chromium-molybdenum Steel which did not meet Physical Specification. 500 x. Fig. 24—Oxide Inclusions in Hardened Chromium Bearing Steel. 500 x.

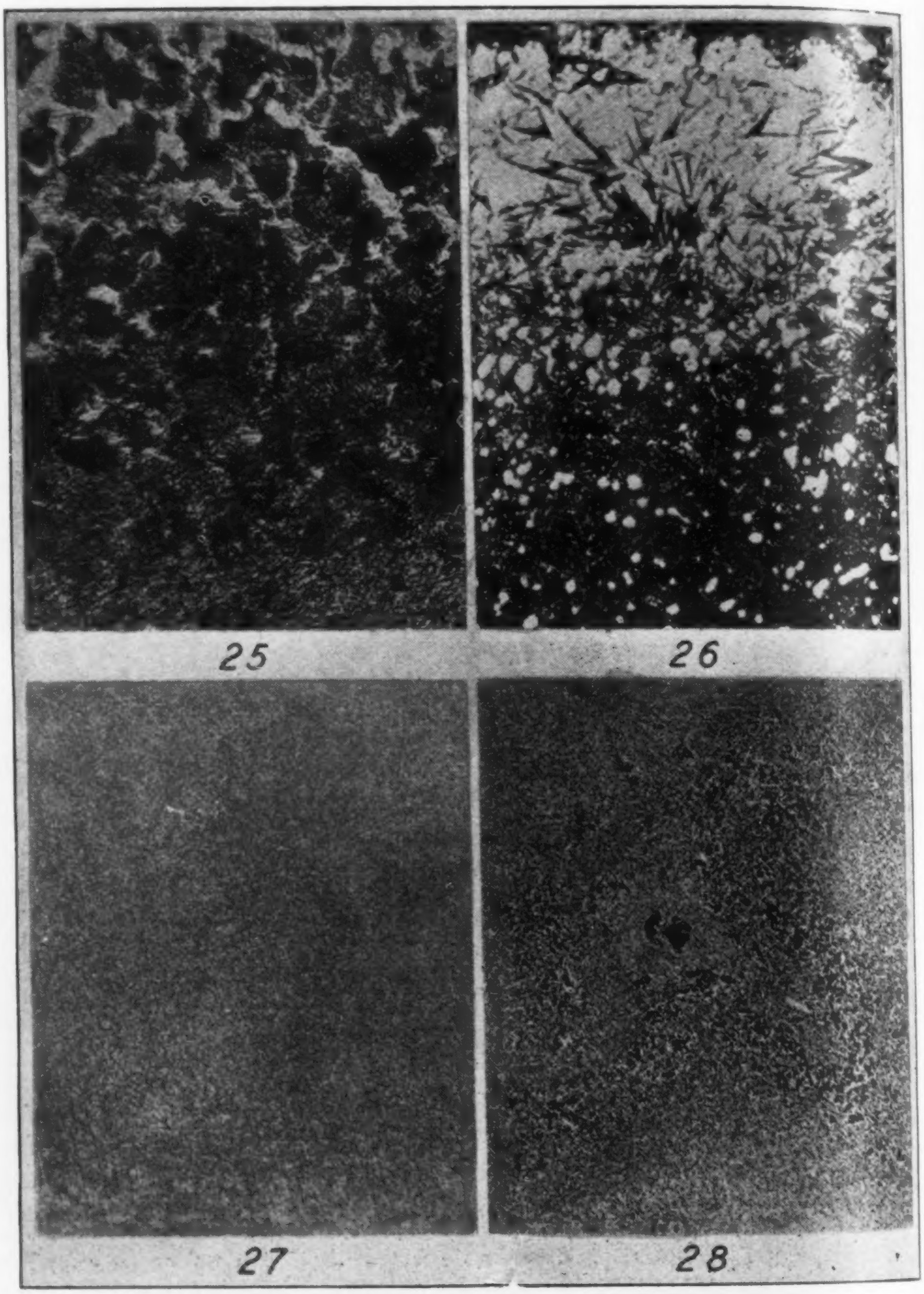


Fig. 25—Decarburization Shown by Approximately 1.00 per cent Carbon Steel—Annealed Condition. Total Depth Approximately 0.030 Inch. Ferrite Zone Approximately 0.015 Inch. 125 x. Fig. 26—Decarburization Shown on Small High Speed Drill, as Result of Oxidizing Furnace Conditions in Hardening. 500 x. Fig. 27—Deep-Etch Test on Cross Section of ¾-inch Square Chromium-molybdenum Steel Showing Uniform Condition. Etching Time Approximately ½ Hour in 1:1 Hot Hydrochloric Acid. Fig. 28—Deep-Etch Test on Similar Section to Fig. 27 Showing Nonuniform Condition Largely the Result of Ferrite Segregation.

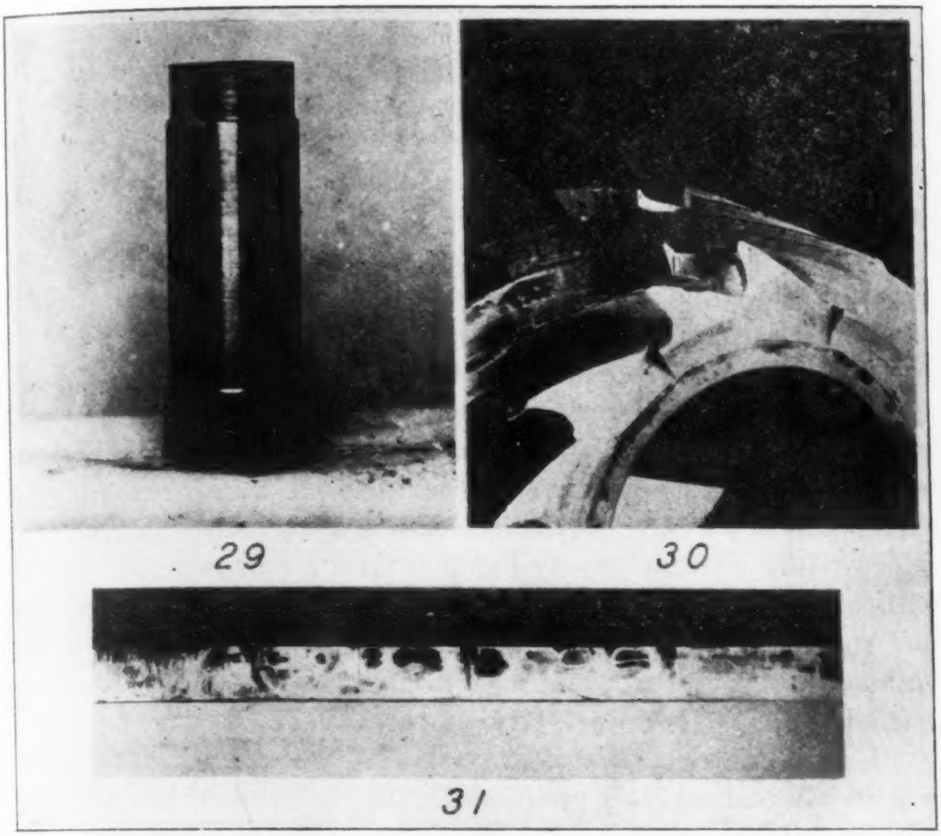


Fig. 29—Step-down Test on Chromium-vanadium Bar Stock Showing Internal Seams. Fig. 30—High Speed Milling Cutter Showing Grinding Cracks. Fig. 31—Shear Blade of High Speed Steel Showing Cracks which were the Result of Grinding.

Under the first—GREATER CONTROL—We should, however, obtain the very best and most modern equipment available commensurate with our means and then see to it that it is properly used, remembering that a fine furnace and an accurate pyrometer alone does not necessarily turn out perfect tools. They must always be intelligently used to aid the operator who after all is the one held responsible for the results. So often no expense is too great for proper engineering and machine operations but any old kind of a set up is good enough for the hardening room. This is not as prevalent today as it was five or ten years ago—thanks to the American Society for Steel Treating and its educational program—but it still exists in many plants, and the heat treaters in such plants should insist on proper equipment to insure accurate work.

As a further suggestion under this heading, it should be the

endeavor to keep accurate records of the heat treatments given and to work out a standardized schedule for time and temperature covering each type and size of tool. The performance of tools should be followed up in order to learn when best results are obtained and especially failures should be run down for the purpose of learning definitely their cause so that in the future they can be corrected. Work out specifications covering the several types of tool steels necessary for requirements and heat treatments should be worked out wherever possible.

Regarding the second general heading CO-OPERATION—May we suggest greater co-operation between the tool maker and the tool steel manufacturer. Submit your problems to him and consult him freely and frequently. It has been the writer's experience that many apparently impossible things have been corrected and improved by working closely together with a customer and always with a mutual benefit. In the matter of correct application the tool steel maker can be of utmost assistance to the user, but first he must be given all the facts and details. Getting a proposition started off right is 50 per cent of the accomplishment.

Under this same heading may we suggest a greater co-operation in the tool maker's plant itself, that is between the purchasing department, the machine department and the heat treating department. Too often there is lack of co-ordination in these three departments, with the heat treating end most frequently suffering. It is not fair to ask the hardener to turn out uniformly good tools when he is furnished with an inferior grade for the purpose, or as is sometimes the case five or six kinds of steel for the same job. Again in designing tools the hardener should be consulted as to details which affect heat treatment and the type of steel to be used. On the other hand the hardener should prepare himself to answer these important questions and maintain at all times an open mind toward suggestions and new information.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

THE CONSTITUTION OF STEEL AND CAST IRON PART VI

BY F. T. SISCO

Abstract

The present installment, the sixth of the series, discusses the effect of the various elements, other than carbon, added to or present as impurities in the normal carbon steels. These elements found in practically all carbon steels are manganese, silicon, sulphur and phosphorus. In addition to these elements most steels contain traces and occasionally appreciable amounts of foreign matter such as slag and other nonmetallic inclusions, and gas. The effect of the common elements and the more prominent impurities on the structure and physical properties of the carbon steels are discussed.

IN our discussion of the constitution of steel in the previous installments we have looked upon it as an alloy of iron and carbon. It is true that carbon is the most important element in ordinary steel, and gives to it its remarkable variation of properties. By controlling the physical condition of the carbon (and its compound, iron-carbide) we are able to make our steel so soft and ductile that we can draw it out cold into a wire no larger than a hair. On the other hand, we can make it so hard and brittle that it will scratch glass and will shatter like glass if struck a light blow with a hammer.

We know so well how to control the condition of the carbon that if our steels were pure iron-carbon alloys many of our troubles would be over. It happens, however, that in our iron ores certain undesirable elements, notably sulphur and phosphorus, are present. Even with all of our skill we are not able to get rid of these entirely and they appear in varying small amounts

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in our finished product. We have found by experience that these two elements always present in our steels are harmful, consequently as we cannot eliminate them entirely we must study their habits so we will be able to anticipate any possible ill effects coming from them.

Experience has taught us that the only practical and economical way to make steel is to refine it when it is molten. Molten iron will dissolve or hold in suspension relatively large amounts of liquid and solid impurities and relatively large volumes of gas; both would be harmful if retained in the finished metal. Hence it is necessary to add certain elements such as manganese and silicon, which serve as scavengers and remove these harmful impurities either wholly or in part. To do this we must add an excess of the purifying element. Consequently, in our discussion of the constitution of steel, we must take into account the presence of manganese and silicon which we will find, in varying amounts, in practically all carbon steels.

It is unfortunate, but true, that ofttimes minute amounts of impurities will exercise a marked effect on the structure and hence on the properties of the metal. For example, steel containing only 0.150 per cent sulphur may be so brittle when hot that it cannot be rolled.

We are sometimes able to identify and study the impurities in steel by means of the microscope, but not for all however. In some cases we must form our conclusions from observations of conditions resulting from a study of the properties of steels containing varying amounts of impurities. A large amount of work has been done on impurities in steel and we now feel fairly sure of ourselves in understanding their behavior.

Silicon

Silicon is found in all steels, in amounts varying from a trace to as much as 0.30 to 0.40 per cent[74]. Silicon is used principally as a degasifying agent and is added to remove the final traces of gas from high grade steels. It is rarely used in steels made by the Bessemer process, occasionally in the basic open-hearth and almost always in the basic electric and crucible processes. In the acid open-hearth and acid electric, silicon enters in the normal reactions of the process and so it is often not necessary to add it. In

[74]Some steels to which silicon is added as an alloying element contains between 0.40 and 3.0 per cent of this element.

high grade steels silicon is usually present in amount ranging from 0.10 to 0.40 per cent.

The principal reaction between silicon and gas may be expressed as

$$Si + 2CO \rightarrow 2C + SiO_2$$

The silicon in excess of the amount necessary to react with the carbon monoxide gas reacts with the iron to form iron silicide, FeSi[75]. This compound is soluble in iron, both when molten and solid, consequently silicon exists in steel as a solid solution of iron silicide in iron. If we calculate the formula weights of iron silicide we will find that one part of silicon forms three parts of iron silicide[76].

In our discussion of solid solutions we have noted that when a small amount of an element or compound dissolves in another element to form a solid solution, the metallographic structure is usually unaffected. This is the case with silicon. The small amount of iron silicide dissolved in the iron cannot be detected by the microscope.

It is reasonable to suppose that silicon in the small amount usually present would not affect the physical properties greatly, and this is the case. However, steels containing silicon often have somewhat better properties than similar steels which have only a trace present. This is due to the fact that silicon promotes soundness, rather than to any direct effect of the silicon.

The silicon dioxide (SiO_2) formed by the reaction noted above is classed as a nonmetallic impurity. Theoretically none of this remains in the steel. When it does it is usually in combination with manganese oxide or iron oxide and is then known as a silicate inclusion. This will be discussed later.

Phosphorus

Phosphorus is present in all iron ores. As it cannot be wholly eliminated by refining processes it is present in commercial steels in amounts ranging from 0.010 to 0.100 per cent. In carbon steels made by the basic open-hearth process the amount will be less than 0.040 per cent; in high grade basic electric steels it is usually below 0.030 per cent and often below 0.020 per cent.

[75]Some investigators give the composition of the silicide as $FeSi_2$

[76]Atomic weight of Fe = 56; Si = 28; Then FeSi = 84
84 : 28 : : x : 1
X = 3

Phosphorus combines readily with iron to form the definite chemical compound iron phosphide, Fe_3P, which in small amounts (less than 0.100 per cent phosphorus) is soluble in iron. Hence phosphorus as iron phosphide is in solid solution in the iron. A simple calculation will show that one part of phosphorus will form six parts of iron phosphide[77].

The small amounts of phosphorus present in ordinary carbon steel, being in solid solution in the iron cannot, ordinarily, be detected by the microscope.

Phosphorus is known to segregate when steel crystallizes from its melt. It apparently tends to collect in those portions of the large dendritic crystals last to solidify. The researches of Stead have shown phosphorus that expels the carbon from the areas into which the former has segregated. Thus phosphorus-rich areas are usually low in carbon. When steel containing segregated phosphorus is rolled the phosphoric areas of ferrite from which the carbon has been expelled tends to elongate into well defined bands such as are shown in Fig. 34.

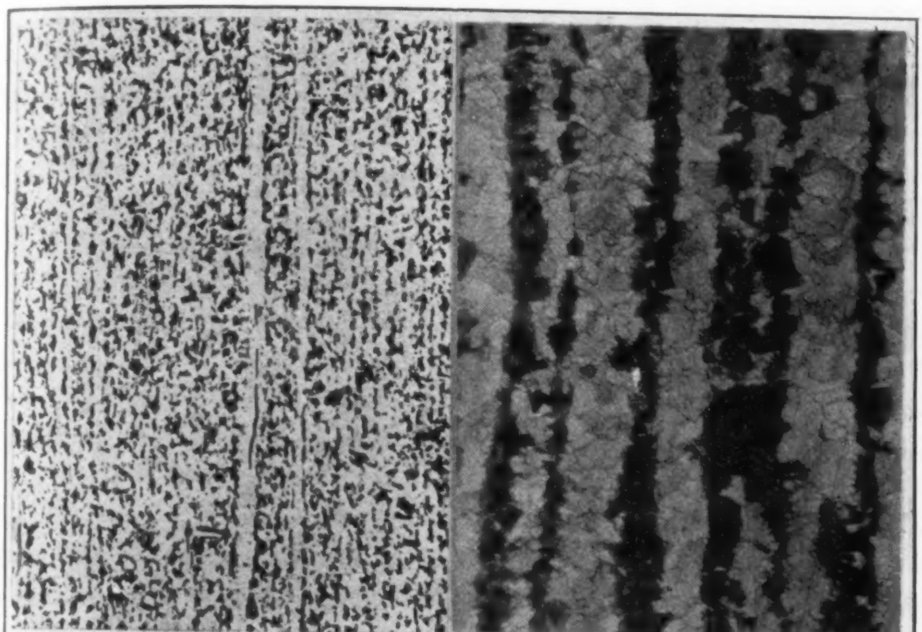
When steels contain a relatively large amount of phosphorus (0.060 per cent and above) there will be banding present more often than not. On the other hand many steels contain a banded structure in which phosphorus is not segregated. Such a steel is shown in Fig. 35 in which the phosphorus is only 0.017 per cent.

Contrary to the action of carbon, phosphorus diffuses with difficulty. Consequently if a steel containing segregated phosphorus and a banded structure such as shown in Fig. 34 is heated to above the critical range and held for a considerable time the phosphorus will not diffuse appreciably from the ferrite bands into the pearlite areas. The carbon will diffuse from the pearlite into the phosphorus-rich ferrite, but on cooling through the critical range will be again expelled and the ferrite bands will persist in their original form.

Phosphorus is thought to produce brittleness when the steel is at atmospheric temperature. The steel is then spoken of as *cold-short*. This is only noticeable when the phosphorus percentage is relatively high (0.100 per cent or above). Phosphorus is believed to enlarge the crystalline grains. This tendency has been offered as an explanation of cold shortness.

[77]Atomic weight of Iron = 56; Phosphorus = 31. Then iron phosphate = 199. Then 199 : 31 : : x : 1
X = 6.4 or 6 approximately.

In certain grades of steel phosphorus is desirable. In sheet about 0.100 per cent is necessary to prevent the sheets sticking together in rolling. A phosphorus content of 0.065 to 0.100 per cent



34 35

Fig. 34—Photomicrograph Showing a Banded Structure Due to Segregated Phosphorus in a Medium Carbon Steel. The Phosphorus Content was 0.121 per cent. Etched in Alcoholic Nitric Acid. Mag. 100 x. Fig. 35—Photomicrograph Showing a Banded Structure Due to Phosphorus Segregation in a Medium Carbon Steel Having a Phosphorus Content of 0.017 per cent. Mag. 260 x.

is desirable in basic open-hearth steels made into galvanized telegraph and telephone wire. Phosphorus apparently increases the adherence of the zinc coating.

Phosphorus increases the tensile strength and hardness and decreases the ductility. Campbell states that each 0.01 per cent of phosphorus increases the tensile strength 1000 pounds per square inch.

When phosphorus is not segregated it cannot be detected by the microscope. When steel contains relatively high phosphorus and the structure shows a characteristic banding, phosphorus segregation is indicated. This may be confirmed by etching the specimen with Stead's or Heyn's reagent.[78].

[78]See Sauveur, Metallography and Heat Treatment of Iron and Steel, 1926. Page 506.

SULPHUR

Sulphur is always present in carbon steels. The amount varies from 0.010 per cent or a little less to as much as 0.150 per cent. Some iron ores contain a little sulphur; most of the amount which is found in steel comes from the fuel used in refining the metal. Sulphur is removed from steel with great difficulty, more so than in the case of phosphorus, consequently in commercial carbon steels the average sulphur content is likely to be higher than the average phosphorus content.

When steel contains no manganese, sulphur reacts with iron, resulting in the definite chemical compound iron sulphide, FeS, which forms a eutectic with iron. This eutectic which is assumed to contain about 85 per cent iron sulphide and 15 per cent iron melts at a low temperature, about 1750 degrees Fahr. (950 degrees Cent.) according to Sauveur. Iron sulphide melts at about 2200 degrees Fahr. (1200 degrees Cent.) or at least 500 degrees Fahr. below the melting point of the steels.

The iron sulphide or iron-iron sulphide eutectic, as the case may be, tends to collect at the grain boundaries as a network or envelope as shown in Fig. 36 from Sauveur.[79] If steel containing iron sulphide or the iron-iron sulphide eutectic is heated, at rolling temperatures (2200 degrees Fahr.) or above the sulphide which is located at the grain boundaries melts. When this constituent is molten even a trace is sufficient to destroy the cohesion of the grains and the steel becomes very brittle when hot. Steel containing as little as 0.050 per cent sulphur, if no manganese is present will crack or even break into fragments in rolling or hammering.

When steel is brittle when hot it is known as *red-short*.

At steel-making temperatures manganese has a much greater affinity for sulphur than iron. As soon as manganese is added to the molten bath the following reaction takes place:

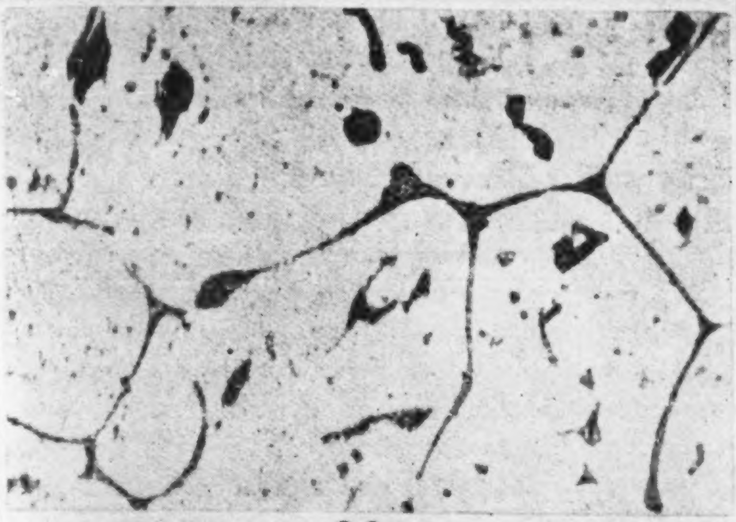
$$FeS + Mn \rightarrow MnS + Fe$$

From the above reaction it will be noted that one part of sulphur requires 1.7 parts of manganese to form 2.7 parts of manganese sulphide. Theoretically, if steel contains 0.05 per cent sulphur, 0.08 per cent manganese is sufficient to combine with it.

[79]Loc. Cit., page 75.

In carbon steels the manganese is at least 0.35 per cent or four times the amount necessary, hence in commercial steels no iron sulphide should be present.

It has been found by experience that it is necessary to have



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37

Fig. 36—Photomicrograph of Iron Sulphide in Steel. Unetched. Mag. 100 x. After Sauveur. Fig. 37—Photomicrograph Showing Manganese Sulphide in a Low Carbon Steel. Etched with Alcoholic Nitric Acid. Mag. 100 x.

the manganese content four to eight times the sulphur content to insure that the steel will be free from red-shortness.

Levy in his researches found that manganese and iron sulphides are readily soluble in each other in the solid state; the manganese sulphide being capable of holding at least 50 per cent iron sulphide in solid solution. He claims that even though more than sufficient manganese is present, the mass action exerted by the large volume of iron is so great that some iron sulphide will persist.

The exact melting point of manganese sulphide is not known, it is probable, however, that it melts at approximately 2560 degrees Fahr. (1400 degrees Cent.) or nearly that of the molten bath.

With this high melting point, manganese sulphide should not segregate to any great extent. It is known, however, that manganese sulphide does segregate, hence it is probable that in commercial steels containing 0.035 to 0.065 per cent sulphur, unless the manganese is high, a little iron sulphide is in solution in the manganese sulphide thus lowering the solidification point and causing this impurity to segregate.[80]

Manganese sulphide is readily identified by the microscope. It appears in castings as round areas, slate gray in color. In hot-worked sections the manganese sulphide inclusions are elongated in the direction of rolling. Fig. 37 shows typical manganese sulphide inclusions in a low carbon steel. In this section they had been elongated in the direction of rolling. Fig. 38 shows the appearance of a large rounded manganese sulphide inclusion at high magnification. A small amount of a silicate inclusion will be noted at the lower edge of the manganese sulphide. Fig. 39 shows an elongated slag inclusion at high magnification, containing manganese sulphide together with manganese and iron silicate.

In addition to the characteristic appearance of manganese sulphide when viewed by the microscope the presence of sulphur in steel may also be detected by sulphur printing.[81]

If but a small amount of sulphur is present in steel and all of it exists as manganese sulphide, its effect on the physical properties is slight. Often carbon-free iron (ferrite) will crystallize around a manganese sulphide inclusion (see Figs. 34 and 37).

Some writers think that manganese sulphide in steel increases the brittleness of the metal under shock. From the investigation

[80]On the other hand McCance does not believe that MnS contains FeS in solution. See Sauveur, loc. cit., page 75.

[81]See Sauveur, loc. cit. page 468.

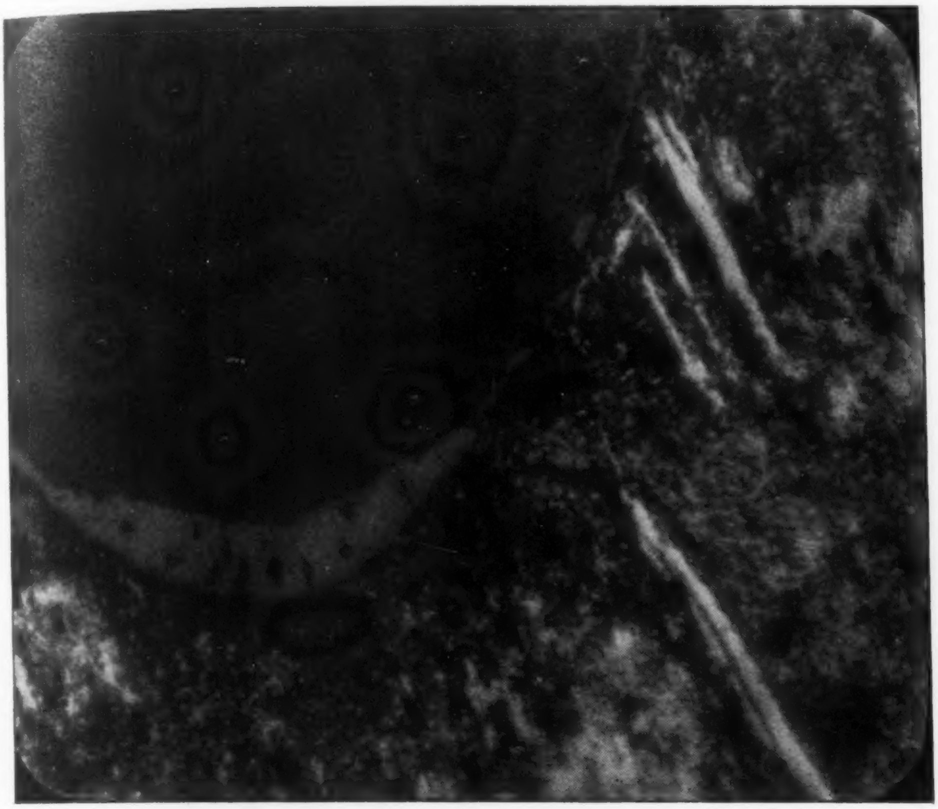

Fig. 38—Photomicrograph Showing a Manganese Sulphide Slag Inclusion in a Specimen of Steel. A Small Amount of Silicate Inclusion will be Noted in the Lower Edge of the Manganese Sulphide. Etched with Alcoholic Picric Acid. Mag. 300 x.

of a large number of failures of steels in aircraft construction there is no doubt but that fatigue and impact failures frequently start from a colony of manganese sulphide inclusions.

Low carbon steel which contains about 0.150 per cent sulphur is used for screw stock and other automatic machine work where its free cutting properties are desirable. The high sulphur content increases the machining properties of the steel, the chips come from the tool in small pieces instead of long curls.

Manganese

In addition to its valuable property of combining with the sulphur and putting this element into a relatively harmless state, manganese is also an efficient scavenger, reacting with oxides in the metal according to the typical reaction:

$$Mn + FeO \rightarrow MnO + Fe$$

A relatively large amount of manganese is always added to

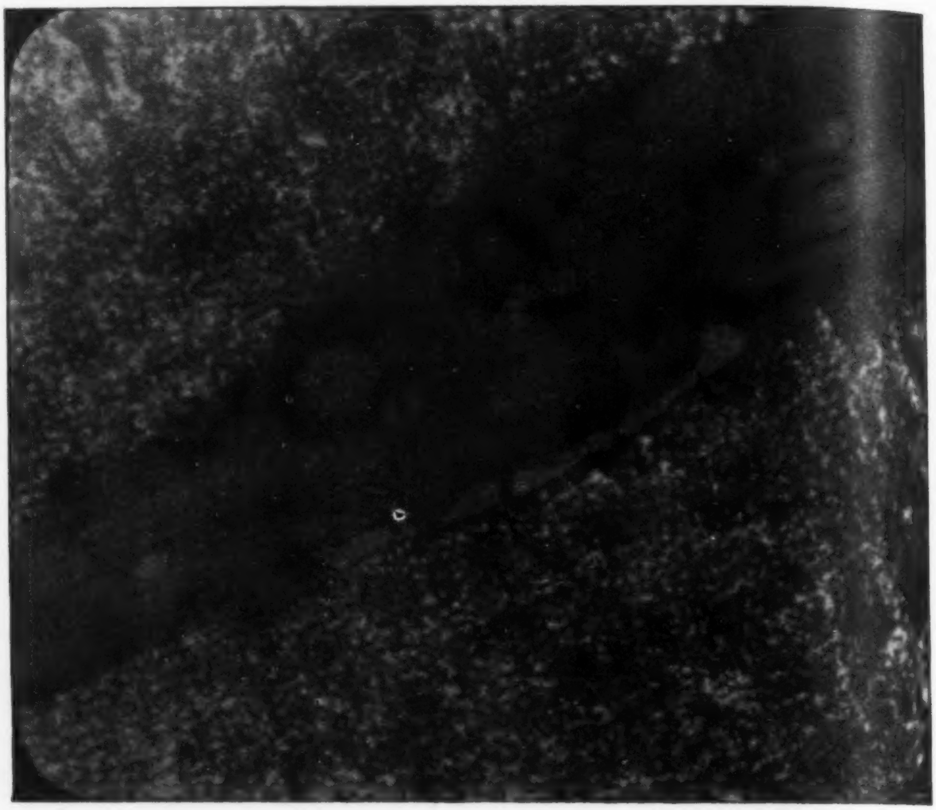

Fig. 39—Photomicrograph Showing an Elongated Slag Inclusion Containing Manganese Sulphide Together with Manganese and Iron Silicate. Etched with Alcoholic Picric Acid. Mag. 3000 x.

steel to insure that all of the sulphur is in the form of manganese sulphide and to insure that the deoxidizing reactions such as the one above are completed. The excess reacts with carbon

$$3Mn + C \rightarrow Mn_3C$$

to form manganese carbide, Mn_3C, a definite chemical compound akin to iron carbide in properties and associated with the latter in cementite. It follows then that in commercial steels cementite is not iron carbide, Fe_3C, as we have assumed in our previous discussion, but a mixture of iron carbide and manganese carbide. This will make no difference in our methods of calculating the structural composition of steel. Manganese and iron have practically the same atomic weight (55 and 56 respectively) so the relationship that one part of carbon forms 15 parts of cementite still holds true irrespective of the amount of manganese.

In the amounts found in ordinary commercial steel (0.25 to 0.70 per cent) manganese as manganese carbide cannot be de-

tected by the microscope and exercises but little effect on the properties. The principal effect of manganese is to produce soundness by the formation of manganese sulphide and by freeing the steel from harmful oxides and gases.

Solid Nonmetallic Inclusions and Gas

All steel contains a certain amount of foreign matter, resulting either from the chemical reactions of refining within the metal or picked up by contact between the molten metal and the slag or the refractories of the furnace or ladle. Practically all of the nonmetallic impurities introduced into or which are in the metal during refining have such a low specific gravity that they find their way to the surface and join the slag. In case the inclusions are finely divided or in case there is not sufficient time for them to reach the top they will remain entrapped in the steel as solid particles of foreign matter known by the various terms, "nonmetallic inclusions, sonims, dirt, slag spots, etc.".

These nonmetallic inclusions are principally reaction products from the action of silicon or manganese on ferrous oxide or dissolved or occluded gas. No steel is entirely free from them. It is possible, however, by using care in melting to produce a product having an almost negligible amount. Well-made crucible steel should be almost entirely free from inclusions; high grade electric steel probably ranks next in purity, with open-hearth and Bessemer last.

These inclusions may be oxides such as ferrous or manganese oxide (FeO or MnO), silica (SiO_2) or alumina (Al_2O_3) or more commonly they may consist of silicates of iron and manganese ($FeSiO_3$ or $MnSiO_3$). The silicates are the reaction products of manganese oxide or iron oxide and silica; for example:—

$$FeO + SiO_2 \rightarrow FeSiO_3$$

In general the oxides, especially silica or alumina, are exceedingly refractory and probably are solid and insoluble in molten steel. On the contrary the silicates usually melt at a temperature much below the solidification point of the steel and so are likely to segregate into particles of appreciable size in that metal that is last to solidify, either in the individual crystal or the steel ingot or casting as a whole.

As a result we frequently find silicate inclusions with the

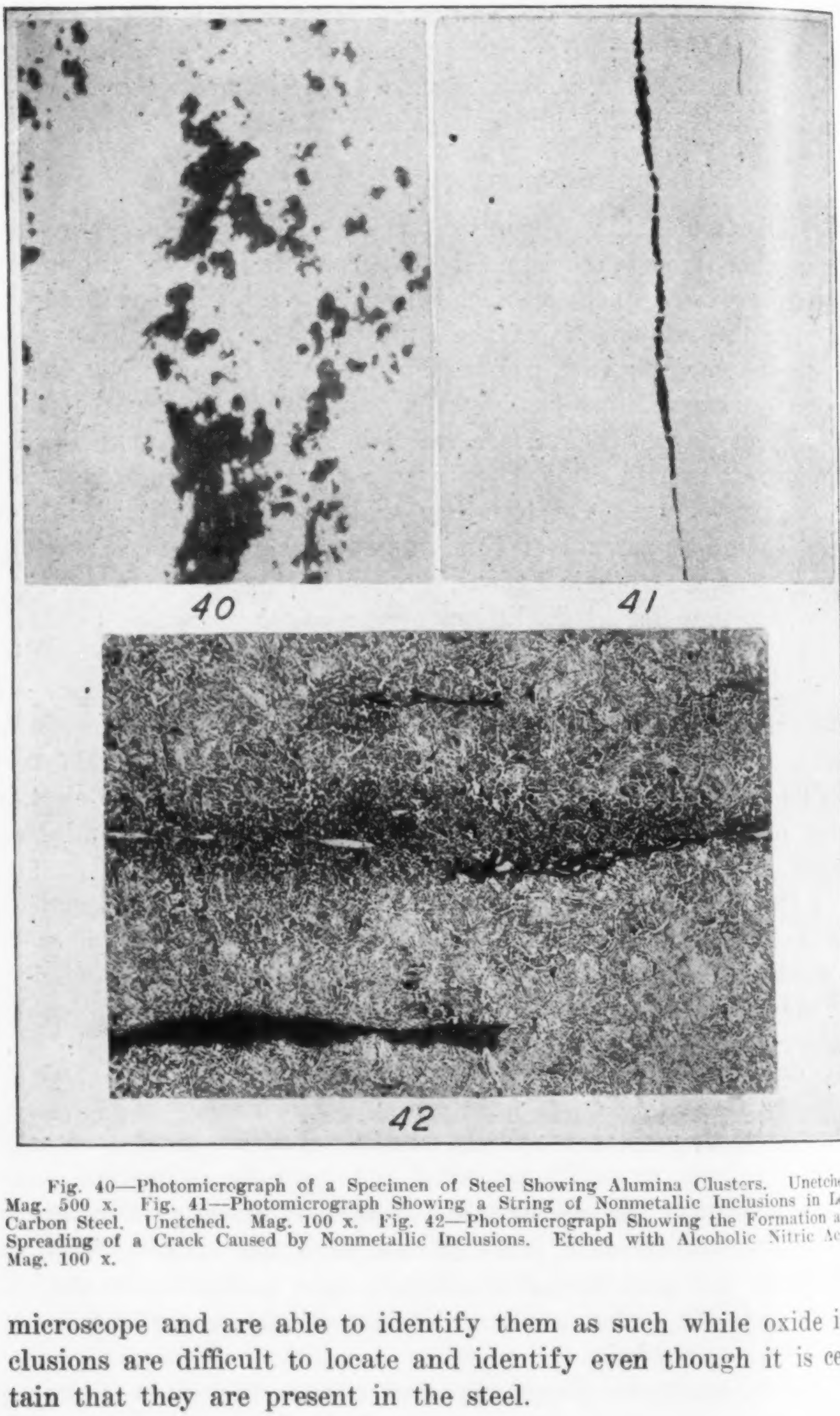

Fig. 40—Photomicrograph of a Specimen of Steel Showing Alumina Clusters. Unetched. Mag. 500 x. Fig. 41—Photomicrograph Showing a String of Nonmetallic Inclusions in Low Carbon Steel. Unetched. Mag. 100 x. Fig. 42—Photomicrograph Showing the Formation and Spreading of a Crack Caused by Nonmetallic Inclusions. Etched with Alcoholic Nitric Acid. Mag. 100 x.

microscope and are able to identify them as such while oxide inclusions are difficult to locate and identify even though it is certain that they are present in the steel.

When alumina (Al_2O_3) inclusions are present they can at times be identified as they have a tendency to collect into clusters as shown in Fig. 40. This inclusion is not plastic at rolling temperatures and so is not elongated by hot working, although it

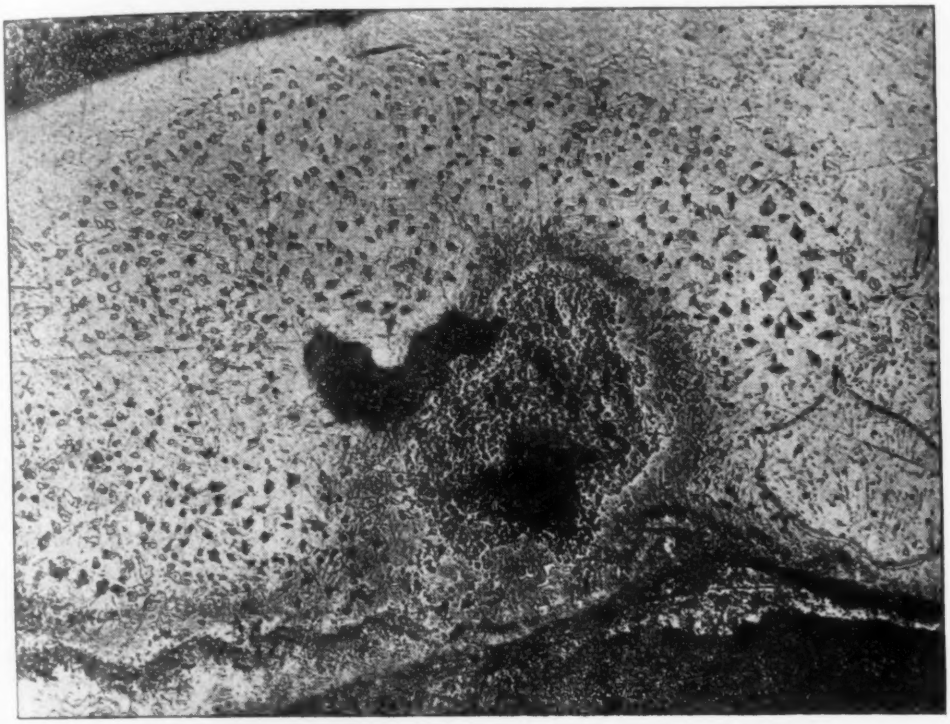

Fig. 43—Photomicrograph Showing Blowholes in a Low Carbon Steel. Etched with Alcoholic Nitric Acid. Mag. 100 x.

will be noted in Fig. 40 that there is a slight tendency for the alumina particles to become generally stretched out in the direction of rolling.

Inclusions of other oxides cannot be identified nor are there any certain metallographic tests by which oxides can be differentiated from silicates.[82] With the exception of manganese sulphide, the silicates are the most numerous of the inclusions that can be seen by the microscope. In the unetched section a string of nonmetallic inclusions, probably silicates has the appearance shown in Fig. 41. When etched the silicates are generally of a different color than the manganese sulphide. Silicates are often found in conjunction with MnS inclusions as is evident in Figs. 38 and 39.

[82]See Sauveur, Loc. Cit., page 82.

In Fig. 37 a string of inclusions, probably silicates, is located just below and slightly to the left of the manganese sulphide stringers. Silicate and other inclusions are frequently a starting point for failure. Fig. 42 shows the mechanism of crack formation in a forging made of dirty chromium-vanadium steel. The central crack started in a colony of slag inclusions and would have spread to the left along the line of inclusions and segregation shown in the center of the micrograph. The lower crack likewise started in a colony of slag inclusions and had spread to the right until it stopped in the sound metal as shown in the lower center of the micrograph.

Although microscopic examination does not always serve to identify an inclusion conclusively, it usually tells us that inclusions are there and that we should be on our guard if there are many of them or if they are badly segregated.

Very little is known definitely concerning the possible presence of gaseous impurities in steel unless there is sufficient present to cause cavities of appreciable size visible by the microscope or unaided eye. The gases which are commonly considered to be present in commercial steels are hydrogen, nitrogen, carbon monoxide and possibly oxygen. Nitrogen forms nitrides which have been identified by the microscope. Carbon monoxide which is more soluble in steel when molten than when solid is expelled from solution when the metal solidifies and forms cavities ranging from submicroscopic in size to those that are an inch or more in diameter. Fig. 43 shows a blowhole near the edge of a piece of steel, with numerous small blowholes around it. It is usually not necessary to make use of the microscope to detect blowholes if this defect is present.

Editor's Note: The next installment will take up the constitution of the hypoeutectic cast irons.

Reviews of Recent Patents

By
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Member of A. S. S. T.

1,607,086, **Alloy Steel and Method of Producing the Same, Harry B. Kinnear, of Marion, Ohio, Assignor to The Marion Steam Shovel Company, of Marion, Ohio.**

It is the object of this invention to provide steel castings having a high tensile strength and high elastic ratio and relatively low shrinkage. The composition of the steel is preferably 0.20 to 0.60 per cent carbon; 0.60 to 0.90 per cent manganese; sulphur and phosphorus below 0.05 per cent; silicon 0.20 to 0.60 per cent and copper 0.50 to 5 per cent. Very satisfactory results are obtained by using 0.90 per cent of copper. The ingot or casting is poured in the usual way and is then given a normalizing heat to approximately 1550 degrees Fahr. for a sufficient time to insure the heat reaching the entire mass, the ingot or casting is then air-cooled, reheated to a temperature between 950 degrees Fahr. and 1025 degrees Fahr. and again air cooled.

1,608,622, **Process for Preventing the Dissolution of Iron and Steel in Suphuric Acid and Pickling Baths, John G. Schmidt, of Milwaukee, and Henry R. Lee, of South Milwaukee, Wisconsin, Assignors to The Newport Company, a corporation of Delaware.**

This patent describes a process of preventing sulphuric acid and other pickling baths from attacking the surface of the iron or steel plates after the scale of iron oxide has been removed. It often happens in the pickling operation that when the sheets are left in the bath too long, not only is the scale removed, but the acid attacks the metal of the sheet causing a pitted and rough surface, depreciating the value of the product. The inventors have discovered that the use of thio-urea or its substitution products in which R represents a hydrogen, alphyl or aryl radical has the property of inhibiting or minimizing the solvent action of the sulphuric acid or pickling bath on the iron and steel.

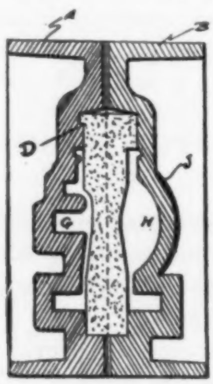
1,607,245, **Manufacture of Metal Alloys, Emil Duhme, of Berlin-Charlottenburg, Germany, Assignor to Siemens & Halske, Aktiengesellschaft, of Siemensstadt, Berlin, a corporation of Germany.**

This patent describes the method of making alloys, whereby the loss of the lower melting point constituents of an alloy during the melting operation may be materially reduced, particularly where the attempt is made to combine powdered elements in their molecular proportions. To form the alloy according to the invention an amalgam is formed between the powdered metals, such as, for example, copper and gold, by combining the proper percentage of each of these metals in powder form with mercury. The mercury is then evaporated from the amalgam, leaving a homogeneous but por-

ous alloy of the desired constituents which can, however, be remelted without material loss of any of the constituent parts. For example, for producing an alloy of 40 per cent copper and 60 per cent gold, the melting point of the alloy is about 1615 degrees Fahr. (880 degrees Cent.), the melting point of the copper is about 1985 degrees Fahr. (1084 degrees Cent.) and the gold about 1945 degrees Fahr. (1063 degree Cent.) Without the use of the mercury amalgam, it was formerly necessary to heat the two mechanically mixed metals to the melting point of copper, resulting in the loss of copper by oxidation and some loss of the gold, whereas by the present invention, after the evaporation of the mercury, a homogeneous alloy is obtained which will melt around 1560 degrees Fahr. (850 degrees Cent.) with no losses from evaporation or oxidation.

1,608,683, Mold-Cooling Means, Stanley M. Udale, of Detroit, Michigan, Assignor to Earl Holley, of Detroit, Michigan.

This patent describes a means for promoting uniform cooling in the various sections of a metal mold, such as D, which comprises coating those



portions of the outside of the mold which normally cool first with an insulating substance, such as J, so as to retard the cooling of these portions and promote more uniform cooling in all portions of the metal mold.

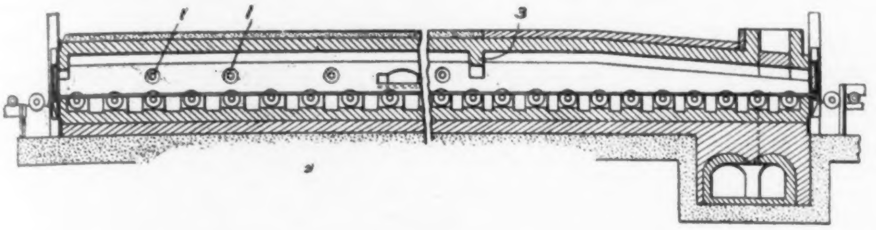
1,610,362, Process for the Treatment of Iron or Steel for Preventing Oxidation or Rusting, Thomas Watts Coslett, of Birmingham, England.

This patent describes an improvement in rust-proofing processes for iron and steel over that described in the inventor's prior patent Nos. 870,937 and 1,007,069, which comprises adding as an additional constituent to the rust-proofing solution a compound of boron, such as, for example, boric acid or borax. The rust-proofing solution is prepared by dissolving 2 ounces of pasty or concentrated acid zinc phosphate and 1-⅓ ounces of boric acid in 1 gallon of water. The concentrated zinc phosphate may be prepared by dissolving 6 ounces of powdered zinc in ½ pint of phosphoric acid and ½ pint of hot water which after setting for a few hours, forms a pasty or powdered mass suitable for making the solution first mentioned.

1,610,567, Annealing of Sheet Steel, Henry S. Marsh and Ralf S. Cochran, of Youngstown, Ohio.

This patent describes a continuous apparatus and method for annealing

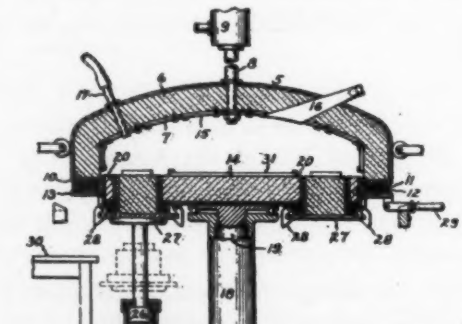
sheet steel which comprises inserting the sheets at the left end of a continuous furnace, such as illustrated, passing them through a nonoxidizing zone heated by the burners 1, to a temperature of 1700 to 1850 degrees Fahr., then cooling quickly, still in the nonoxidizing atmosphere, to a temperature of 1200 to 1400 degrees Fahr., continuing the cooling to a dull red heat, roller leveling the plates and cooling slowly in packs in open air to a tem-



perature of 200 degrees Fahr. or less. Cooling is accomplished by either water cooling the right end of the furnace beyond the bridge-wall 3 or removing the insulation from this end of the furnace so as to form a cooler zone. The process described produces more uniformly annealed sheets which are of smooth appearance and which are more suitable to stand deep drawing operations.

1,610,809, **Electric Furnace, D. F. Newman, of Schenectady, New York, Assignor to General Electric Company, a corporation of New York.**

This patent describes an electric furnace comprising a dome or hood 5 which is supported for vertical movement by the plunger 8 operating in the hydraulic cylinder 9. The hood 5 is suitably insulated by the refractory lining 7 provided with a sight tube 16 and an inlet 17 for nonoxidizing gas.

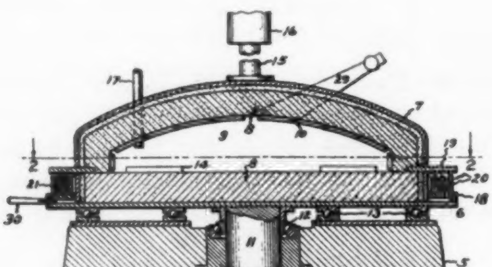


The hood fits over a pedestal 18 which rotatably supports a table 14 provided in the center thereof with suitable resistance elements 31 for heating the furnace. The outer edge of the table 14 provides a seal with the lower edge of the hood 5 by means of a plurality of interfitting plates 11 and 12 which extend annularly around the furnace. At intervals around the outer edge of the table 14, a plurality of supporting platforms 27 are removably supported by means of the hooks 28. The furnace is charged by means of a

hydraulic plunger 26 which, when the hooks 28 are released, is adapted to receive the platforms 27 and lower the same to the level of the table 30, where the heated charge may be removed and the new charge inserted and then to elevate the platforms 27 into the furnace. The table 14 of the furnace is given a step by step rotation past the charging plunger by any suitable means, such as a handle 29. The furnace operating in this way has very slight loss of heat or of the furnace gases at the point of charging.

1,610,819, Electric Furnace, Christian Steenstrup, of Schenectady, New York, Assignor to General Electric Company, a corporation of New York.

This patent describes an electric furnace similar to the one described above, in which, however, the upper hood 7 is lifted by means of the plunger



15 and cylinder 16 to expose the openings in the lower side walls of the hood at the proper points to permit the chargers to be inserted or withdrawn through small openings without substantial loss of heat or furnace gases from the inside of the furnace.

1,598,236, Method of Building and Starting Electric Induction Furnaces, Charles A. Brayton, Jr., Cleveland, Assignor to the Induction Furnace Company, Cleveland.

The method consists in providing a casing for a short-circuited metallic core for forming the channel, in which casing there is sufficient cross-sectional air space to permit lateral displacement of the core when expanding. A refractory lining is packed about the core, and a low current induced in the core to heat it and dry out the lining about the core. The current is then increased to reduce the core to a molten mass.

1,602,995. Nonferrous Alloy. William A. Wissler, Elmhurst ,N. Y., assignor to Haynes Stellite Company, a corporation of Indiana.

A nonferrous alloy suitable for tools for the high-speed cutting of cast iron which contains at least 15 per cent of chromium, at least 10 per cent of another metal of the chromium group and at least 0.40 per cent of boron, with the balance principally cobalt.

THE ENGINEERING INDEX

Registered United States, Great Britain and Canada

Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each month with a specially prepared section of The Engineering Index. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the copy prepared for the annual volume of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,200 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

ALLOYS

HIGH TEMPERATURE-RESISTING. High Temperature Resisting Alloys (Hochhitzebeständige Legierungen), A. Fry. Kruppsche Monatshefte, no. 7, Oct. 1926, pp. 154-172, 9 figs. Details of Ferrotherm, Nichrotherm and Nialit alloys made and patented by Krupps with coefficient of heat transmission of 15 to 25, for temperatures of up to 1100 deg. Cent.

ALUMINUM

ALUMINA IN. Alumina in Aluminum and its Light Alloys, H. J. Anderson. Am. Metal Market, vol. 33, no. 223, Nov. 20, 1926, pp. 5-7 and 15. Discusses question of alumina and other inclusions in aluminum and methods for preventing their occurrence or effecting their removal; consideration of origin of oxide and other inclusions which may be present.

DEVELOPMENTS. Aluminum—The Metal of the Future. Brass World, vol. 22, no. 11, Nov. 1926, pp. 341-342. Developments of recent years show its supremacy in many fields; light weight and hardness are valuable properties; gradually is forcing heavy metals aside.

RATE OF SOLUTION. Rate of Solution of Aluminum (Lösungsgeschwindigkeit des Aluminums), M. Centnerszwer and W. Zablocki. Zeit. für physikalische Chemie, vol. 122, no. 5-6, Aug. 20, 1926, pp. 455-481, 3 figs. Rate of solution of aluminum in dilute hydrochloric acid was determined from measurements of amount of hydrogen evolved; induction period, during which rate of solution increases, is followed by normal solution; it is considered that metallic aluminum is covered with passive film which is continuously transformed to active metal (in presence of acid), and of thickness, as determined from surface area and volume of hydrogen evolved during induction period; rate of solution of aluminum in alkali increases as concentration of alkali decreases. See brief translated abstract in Brit. Chem. Abstracts, Oct. 1926, pp. 1010-1011.

ALUMINUM ALLOYS

ALUMINUM-CADMIUM. Influence of Cadmium on Aluminum, N. F. Budgen. Brass World, vol. 2, no. 11, Nov. 1926, pp. 349-353, 8 figs. Series of tests establishes new facts regarding mechanical properties of these alloys; author's conclusion is that they are not commercially useful.

COMPOUNDS. Influence of $MgZn_2$ on Aluminum Alloys (Der Einfluss der Verbindung $MgZn_2$ auf die Vergütbarkeit von Aluminiumlegierungen), W. Sander. Zeit. für anorganische u. allgemeine Chemie, vol. 154, June 6, 1926, pp. 144-151, 2 figs. No alloy of aluminum will be improved by heat treatment (500 deg. Cent.) and aging unless it contains at least one substance which goes into solid solution in aluminum and shows decreasing solubility with falling temperature; only elements now known to give solid solutions are zinc, copper, magnesium, silicon, lithium and beryllium; a particularly useful compound is $MgZn_2$.

HEAT TREATMENT. A Rapid Method for the Heat Treatment of the Aluminum-Copper-Nickel-Magnesium (Piston) Alloy, S. Daniels. Am. Soc. Steel Treat.—Trans. vol. 10, no. 6, Dec. 1926, pp. 872-882. Outlines principles of heat treatment of "Y" alloy, together with course of experimentation that led to adoption of two-hour treatment which increased strength of alloy as cast from 25,000 to 35,000 lbs. per sq. in., and Brinell hardness from 74 to 105; effect of time at soaking temperature, quenching medium, aging temperature and period, and influence of cross-section upon mechanical properties.

PROPERTIES. Useful Alloys of Aluminum and Their Properties, G. R. Webster. Foundry Trade Jl., vol. 34, no. 533, Nov. 4, 1926, p. 393. Gives properties of different alloys of aluminum, which are divided into three general groups: (1) aluminum with not more than 10 to 25 per cent of added metals; (2) metals containing not more than 10 to 15 per cent of aluminum; (3) alloys of rare

metals with aluminum containing from 0.5 to 5.0 per cent of added metal.

SAND-CAST. Properties of Some Sand-Cast Aluminum-Magnesium Silicide Alloys, S. Daniels. Indus. & Eng. Chem., vol. 18, no. 12, Dec. 1926, pp. 1280-1285, 14 figs. When quenched and artificially aged those quasi-binary alloys which contain from 1.25 to 1.75 per cent of this compound, develop excellent combination of strength and ductility; benefits to be derived from heat treatment of such alloys are to be utilized rather in wrought materials; describes metallography.

STREET-CAR CONSTRUCTION, FOR. Street Cars of Aluminum. Iron Age, vol. 118, no. 24, Dec. 9, 1926, p. 1633. Aluminum street car built by Cleveland Ry. Co. for experimental purposes; aluminum-alloy parts of car are in form of forgings, castings, light plates, tubing and standard formed sections; few parts of body are of steel.

ALUMINUM BRONZE

PROPERTIES. Aluminum Bronze—An Acid Resisting Material, W. M. Corse. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926. pp. 898-905. Practically important aluminum bronzes are those containing less than 11 per cent aluminum; they possess, in addition to tensile properties of medium steel, far greater resistance to corrosion, wear and fatigue than such steel; aluminum bronze may be forged and machined with practically same equipment as for steel, and with proper care and fluxes it may be welded; properly designed castings have been made to stand hydraulic pressure of 1000 lbs. per sq. in.

BEARING METALS

PROPERTIES. Bearing Metals, W. T. Griffiths. Inst. Mar. Engrs.—Trans., vol. 38, Sept. 1926, pp. 180-200 and (discussion) 200-207, 16 figs. Deals with tin-base, lead-base, and copper-base alloys; effect of casting on microstructure; testing; lubrication.

BEARINGS

BABBITTING. Electrically Heated Babbitting Process. Elec. World, vol. 88, no. 20, Nov. 13, 1926, pp. 1019-1020, 1 fig. Describes first complete installation by street railway of electrically heated babbitting equipment installed by Los Angeles Railway; installation consists of three electrically heated and automatically controlled General Electric melting pots and preheating oven.

BEARINGS, ROLLER

HEATING AND ANNEALING. Timken Bearings and Gas Furnaces, F. W. Manker. Iron Age, vol. 118, no. 23, Dec. 2, 1926, pp. 1549-1551, 5 figs. Data on fuel consumption and other features of heating and annealing practice; scrap reclamation by briquetting.

BLAST FURNACES

DESIGN. Some Practical Features of Blast Furnace Construction, W. G. Imhoff. Am. Metal Market, vol. 33, no. 223, Nov. 20, 1926, pp. 3-5, 13 figs. Deals with hearth, bosh and inwalls.

GRANITE CITY, ILL. Complete 700-Ton Blast Furnace, R. A. Fiske. Iron Age, vol. 118, no. 20, Nov. 11, 1926, pp. 1341-1343, 3 figs. Second stack at Granite City permits expansion of boiler equipment and erection of electric power plant; surplus power sold.

GREAT BRITAIN. Blast Furnaces of the United Kingdom. Foundry Trade Jl., vol. 34, no. 532, Oct. 28, 1926, supp. plate. Quarterly report containing tabular data compiled from returns received direct from furnaces.

600-TON. Places Modern Stack in Blast, J. E. Knox. Iron Trade Rev., vol. 79, no. 23, Dec. 2, 1926, pp. 1418-1421 and 1434, 6 figs. Details of new furnace installed by Central Steel Co., Massillon, O.; hot metal from new 600-ton furnace is transferred in mixer-type ladles either to double-strand pig machine or direct to steel works; all flue dust and gas washer sludge is sintered.

BOILER TUBES

ELEVATED TEMPERATURES, AT. Properties of Boiler Tubing at Elevated Temperatures Determined by Expansion Tests, A. E. White and C. L. Clark. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. Dec. 6-9, 1926, 17 pp., 16 figs. Investigation to determine safe working loads for low carbon steel seamless tubing at elevated temperatures; there is increasing tendency to increase both temperature and pressure, but little is known of properties of metals at elevated temperatures, particularly when temperatures are maintained for long periods of time; sets forth preliminary findings on 0.13 carbon steel tubing when loaded at temperatures of 900, 1000, 1250 and 1500 deg. Fahr.

BOILERS

A. S. M. E. CODES. Revisions and Addenda to Boiler Construction Code. Mech. Eng., vol. 48, no. 12, Dec. 1926, pp. 1474-1478, 1 fig. Specifications for carbon steel castings for valves, flanges and fittings for high-temperature service; specifications for carbon steel and alloy steel forgings.

BRASS

ARSENIC, EFFECT OF. The Effect of Arsenic on Brasses. Metal Industry (Lond.), vol. 29, no. 9, Aug. 27, 1926, pp. 191-192, 1 fig. Points out that influence of arsenide depends on whether it is free or in solution and varies with grade of alloy; shows that cheaper arsenical copper can be used with advantage for manufacture of 70-30 brass whereas it is absolutely prohibitive for use in manufacture of 60-40 brass.

CASTINGS. Some Defects in Brass and Bronze Castings. Foundry Trade Jl., vol. 34, no. 535, Nov. 18, 1926, p. 434. Describes defects due to process of manufacture consisting chiefly of presence of impurities, whereas defects arising from after treatment are overheating, overworking welds, etc.; in searching for impurities, direct examination of polished section under microscope may reveal hidden trouble; etching can also be resorted to afterwards if required; oxide inclusions; defects caused during solidification.

EXTRUSIONS. Optimum Temperature for the Extrusion of (Alpha and Beta) Brass (Die günstigste Presstemperatur von (A+B)-Messing), W. Schreiter. Zeit. für Metallkunde, vol. 18, no. 9, Sept. 1926, pp. 285-287, 9 figs. Extrusion experiments on brasses containing 52 to 66 per cent copper show that optimum temperature for extrusion varies with composition of alloy, but is, in all cases, just slightly above temperature at which whole of metal is in the beta form; microstructure of metal extruded at 740 deg. Cent. consists of long parallel lines of alternating alpha and beta, whereas at 760 deg. Cent. it consists entirely of characteristic coarse-

grained crystal structure usually obtained after pressure; annealing at 760 deg. Cent. produces satisfactory beta structure; similar characteristics hold for other brasses containing 52 to 66% copper.

See brief translated abstract in Chem. & Industry, vol. 45, no. 46, Nov. 12, 1926, pp. 920-921.

BRONZES

PHYSICAL PROPERTIES. The Porosity and Physical Properties of Bronze (Ueber die Porosität und die physikalischen Eigenschaften des Rotgusses), Reitmeister Giesserei-Zeitung, vol. 23, nos. 20 and 21, Oct. 15 and Nov. 1, 1926, pp. 559-564 and 592-596, 18 figs. Work at experimental foundry of German State Railway; processes of solidification in bronze alloys; testing of molding sand; relations between chemical composition and tendency to segregation; physical properties of bronze and results of tests.

STAMPING AND FORGING. Changes in Properties of Bronze with Stamping and Forging (Ueber Aenderungen der Eigenschaften von Zinnbronze beim Pressen und Schmieden), A. Schleicher. Zeit. für Metallkunde, vol. 18, no. 10, Oct. 1926, pp. 322-323, 6 figs. Investigation of a group of bronzes, formerly known as cannon bronze, showed that different kinds of working (stamping and forging) do not affect mechanical and technical properties of metal, but have considerable influence on structure.

STRUCTURE AND PROPERTIES. The Structure and Properties of Bronze (Einiges über den Aufbau und die Eigenschaften von Rotguss), R. Kühnel. Zeit. für Metallkunde, vol. 18, nos. 9 and 10, Sept. and Oct. 1926, pp. 273-278 and 306-311, 24 figs. Effect of impurities, especially bismuth, arsenic, antimony, and lead on a standard bronze used in railway practice for armatures, bearings, etc., of 85 per cent copper, 9 per cent tin and 6 per cent zinc content; auto-deoxidation; occurrence of stannic acid; effect of sulphur and its occurence in structure; compressive strength, hardness, tenacity, workability and structure of series of melts which were produced in order to find a standard alloy as substitute for above-named bronze which is too expensive.

CASE-HARDENING

FURNACE. An Efficient Carburizing Furnace of the Surface Combustion Type, A. E. White and E. R. McPherson. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 941-950 and (discussion) 950-953, 5 figs. New furnace installation in Packard Motor Co., and results of tests run on these furnaces for purpose of determining temperature, distribution and regulation; production capacity; fuel-oil consumption; in author's opinion, ideal type of carburizing furnace is one of compensating type.

ROTARY MACHINES FOR. Rotary Machines for Carburizing, F. S. O'Neil. Iron Age, vol. 118, no. 21. Nov. 18, 1926, pp. 1407-1409, 3 figs. Greater uniformity of product reported; cost figures given; advantages from subsidiary uses.

CAST IRON

COOLING AND CONTRACTION. Note on Cooling and Contraction of Iron Castings, I. Sugimura. Soc. Mech. Engrs. (Japan)—Jl., vol. 29, no. 114, Oct. 1926, pp. 585-594, 3 figs. Presents cooling and contraction curves of rapidly and slowly cast iron from melting to ordinary temperatures obtained by special apparatus of author's own design, and results are formulated in mathematical expressions; density and shrinkage of cast iron which occluded air while pouring. (In English)

GERMAN STANDARDS. Cast Iron (Gusseisen). Maschinenbau, vol. 5, no. 20, Oct. 21, 1926, pp. 965-966. Proposed tentative specifications of the German Industrial Standards Committee (N. D. I.) for testing of different classes of cast iron. See also Giesserei, vol. 13, no. 44, Oct. 30, 1926, pp. 850-852.

GERMAN STANDARDS. Report of German Industrial Standards Committee (NDI-Mitteilungen). Bauingenieur, vol. 7, no. 45, Nov. 5, 1926, pp. 45-48 (Baunormung), 2 figs. Proposed standards for cast iron of various qualities; cast-iron steps (for concrete shafts).

GERMAN STANDARDS. Standardization in Foundries (Normungsarbeiten im Giessereiwesen). Scharlibbe. Giesserei-Zeitung, vol. 23, no. 22, Nov. 15, 1926, pp. 628-630. German N. D. I. tentative specifications for cast iron; general rules for testing, etc.

GRAPHITIZATION. Graphitization at Constant Temperature Below the Critical Point, H. A. Schwartz and H. H. Johnson. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 965-970, 1 fig. This paper is brief sequel to earlier paper by one of the authors; evidence is furnished that mechanism of reaction in its earlier stages at least, is identical above and below critical point; it is shown that apparent permanence of metastable system at atmospheric temperatures is not inconsistent with conception that graphitization proceeds at any temperature, no matter how low.

GRAPHITIZATION. Influence of the Various Elements on the Graphitization in Cast Iron, H. Sawamura. College of Eng., Kyoto Imperial Univ.—Memoirs, vol. 4, no. 4, Sept. 1926, pp. 159-260, 141 figs. Influence of various elements on graphitization in white cast iron; influence of aluminum, nickel, copper, cobalt, gold and platinum, chromium, tungsten, molybdenum, vanadium, phosphorus, sulphur, manganese; theoretical consideration of graphitization; supplemental experiments; graphitization velocity and degree; mechanism of graphitization. (In English)

IMPROVEMENT. Results in Improving Quality of Cast Iron (Etude comparative des résultats obtenus dans l'amélioration des qualitiés des fontes moulées), L. Piedbeuf. Revue Universelle des Mines, vol. 12, no. 1, Oct. 1, 1926, pp. 2-11, 5 figs. Compares various kinds of cast iron of high resistance by means of Maurer diagram; effect of rapid and slow cooling; graphitization; micrographic study.

NICKEL ADDITION. Improving Gray Cast Iron with Nickel. West. Machy. World, vol. 17, no. 11, Nov. 1926, pp. 501. Gives list of castings for which nickel and nickel-chromium additions are recommended and being successfully used.

PEARLITIC. Perlit Iron, the Maurer Diagram, and other Formulae for Cast Iron. Metal Industry (Lond.), vol. 29, nos. 20 and 21, Nov. 12 and 19, 1926, pp. 467-468 and 491-492, 2 figs. Author challenges question of accuracy and reliability of iron-carbon-silicon diagrams of cast iron, and deprecates too great dependence upon their results; such dependence is not, he considers, justified in

light of present knowledge and is apt to be misleading.

TESTING MACHINES. Modern Cast Iron Testing Machines (Neuzeitliche Gusseisen-Prüfmaschinen), H. Kalpers. Dinglers Polytechnisches Jl., vol. 107, no. 21, Nov. 1926, pp. 240-242, 9 figs. Details of apparatus by various makers for testing tensile strength, hardness, elasticity, limit of elasticity and reduction of profile area.

CHROME-NICKEL STEEL

FLAKES IN. Hair-Line Cracks in Nickel-Chromium Steel, R. H. Greaves. Metallurgist (Supp. to Engineer, vol. 142, no. 3698), Nov. 26, 1926, pp. 167-171, 5 figs. Hair-line cracks referred to are only one type of number of defects described in recent technical literature as flakes in steel; observations made in Research Department, Woolwich, on occurrence and distribution of cracks, having appearance on machined surface of steel of extremely fine cracks of length usually not exceeding 0.5 in.; review of recent work by Bardenheuer on flakes in nickel-chromium steel. See reference to original article by Bardenheuer in Eng. Index 1925, p. 149.

COPPER

COPPER OXIDE, EFFECT OF. On the Influence of Cuprous Oxide on Electrolytic and Refined Copper, H. Altwicker. Continental Met. & Chem. Eng., vol. 1, no. 3, Oct. 1926, pp. 70-74, 4 figs. Review of investigations; results of experiments carried out by author on three different grades of copper, namely: electrolytic copper produced by remelting sheet and wire scrap; refined copper made from oxidic products and containing small amounts of nickel, arsenic, etc.; and refined copper produced from blister copper and containing 0.5 per cent nickel.

CORROSION

FERROXYL INDICATORS. The Ferroxyl Indicator in Corrosion Research, U. R. Evans. Metal Industry (Lond.), vol. 29, nos. 21 and 22, Nov. 19 and 26, 1926, pp. 481-482 and 507-508, 9 figs. Discusses reliability of so-called ferroxyl indicator with special reference to McKay-Liebreich controversy regarding cause of pitting; mechanism of pitting.

GAS INDUSTRY. Some Phases of Corrosion, R. H. Ruthven. Gas World, vol. 85, no. 2207, Nov. 20, 1926, pp. 523-527, 4 figs. Effect of oil filming in external corrosion of holders; graphitization of cast-iron mains; internal corrosion of gas mains and services.

IRON AND STEEL. Iron and Steel: Sulphuric and Nitric Corrosion, S. C. Bate. Chem. Age, vol. 15, no. 383, Oct. 30, 1926, pp. 419-420. Results of experiments in which action of oleum, sulphuric acid and nitric acid of various concentrations and mixtures of these acids on iron and steel were compared with object of discovering relative powers of resistance of iron and steel towards these acids, and any limiting nitric acid or water content in mixed acids at which any considerable corrosion of metal surfaces can be said to begin.

PROBLEMS. Corrosion, J. Mitchell. West of Scotland Iron & Steel Inst.—Jl., vol. 33, Mar.-Apr. 1926, pp. 72-81 and (discussion) 81-87, 1 fig. General statement of established concepts of modern theory and translation of scientific factors which are relevant to application of that theory into terms of practical working conditions; author refers to personal work and experience.

SHELL RIVETS AND PLATES. Corrosion, W. Bennett. Soc. Naval Architects & Mar. Engrs.—Advance Paper, no. 6, for mtg. Nov. 11-12, 1926, 28 pp., 37 figs. Recent examples of corrosion on shell rivet points; explanations advanced; corrosion theories; influence of copper content on steel; application of electrolytic theory; pitting and general corrosion.

CRYSTALS

LARGE SINGLE. Methods of Growing Large Metal Crystals, H. C. H. Carpenter. Metal Industry, (Lond.), vol. 29, nos. 18 and 19, Oct. 29 and Nov. 5, 1926, pp. 409-411 and 437-439. Deals with problem of preparing piece of metal in form of single crystal which is theoretically capable of solution in at least three ways: By production from vapor phase, from liquid phase, and by conversion of ordinary polycrystalline form into single crystal; properties of single crystals; original softness and distortion-hardening; distortion under compression. Sorby Memorial Lecture.

CUPOLAS

COKE COMBUSTION. The Influence of Moisture on the Combustion, Especially of Coke (Ueber den Einfluss der Feuchtigkeit bei Verbrennungsvorgängen, insbesondere bei der Verbrennung von Koks), P. Oberhoffer and E. Piwowarsky. Stahl u. Eisen, vol. 46, no. 39, Sept. 30, 1926, pp. 1311-1320, 4 figs. Experiments on laboratory basis conducted by authors on cupola 1500 mm. high with inner diameter of 220 mm. in tuyere zone; results show that certain amount of moisture has favorable effect on combustion of coke; critical amount of moisture is that where advantage of improved radiation is compensated by heat consumption of endothermic reduction of steam; other experiments showed that moisture had bad effect on ignition temperature and combustibility of coke measured by reduction of CO_2. See also translated abstract in Foundry Trade Jl., vol. 34, no. 535, Nov. 18, 1926, p. 441.

CUTTING METALS

ELEMENTS. A Research in the Elements of Metal Cutting, O. W. Boston. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. Dec. 6-9, 1926, 95 pp., 83 pp. Investigation in fundamental elements of metal cutting conducted in Machine Tool Laboratory at University of Michigan; object of investigation was to determine relation between force on tool in direction of cut for constant cutting speed of 20 ft. per minute, and degrees of tool sharpness, various tool angles, width and depth of cut, and physical properties of materials cut; nine representative types of material were cut including carbon steels, alloy steels, brass, and annealed and unannealed cast iron; cutting was confined to straight-line motion on planer and tools used were of end-cutting type; results indicate, among other things, that there is apparent relation between some of physical properties of metal and their machinability of cutting force on tools. Bibliography.

PROBLEMS. Contribution to the Cutting and Turning of Metals, H. Klopstock. Continental Met. & Chem. Eng., vol. 1, nos. 2, 3 and 4, Sept., Oct. and Nov. 1926, pp. 41-44, 75-77 and 103-104, 14 figs. Describes researches and experiments carried out in Ma-

chine-Tool Testing Department of Technische Hochschule, Berlin; two of most vital problems to be solved were determination of forces involved at cutting edge in turning of cross sections of sizes and study of cutting mechanism involved.

CUTTING TOOLS

ROUGH TURNING. Rough Turning with Particular Reference to the Steel-Cut, H. J. French and T. G. Digges. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. Dec. 6-9, 1926, 69 pp., 22 figs. Tests extend to current commercial high-speed tool and structural alloy steels and portions of Taylor's original investigations in rough turning carbon steels; they were made primarily to show effect upon tool performance of variation in chemical composition and mechanical properties of steel cut and include lathe tests on carbon, nickel, low- and high-chromium, chromium-vanadium, chromium-molybdenum and nickel-chromium steels having tensile strengths between 65,000 and 195,000 lbs. per sq. in.

RESISTANCE OF METALS TO. Work-Hardening Properties of Metals, E. C. Herbert. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. Dec. 6-9, 1926, 43 pp., 37 figs. Seeks to bring into correlation with operation of cutting tools certain groups of well established and generally recognized facts, chief among them being: (1) fact that metals are hardened by any process which deforms them so as to cause permanent change of shape while they are at low or moderate temperatures, process generally referred to as cold work; (2) fact that metals are deformed and are therefore hardened by cutting tools; (3) fact that heat is generated by deformation of metals and in preeminent degree by metal-cutting operations; and (4) degree of hardness induced by working metals with cutting tools, or otherwise is greatly influenced by temperature at which deformation takes place; shows bearing of these correlated facts on resistance offered by metals to cutting tool and on rate of wear of cutting tool.

DROP FORGINGS

TRIMMING. Dies and Presses for Trimming Forgings, E. V. Crane. Forging—Stamping—Heat Treating, vol. 12, no. 11, Nov. 1926, pp. 416-420, 8 figs. Discusses various types of dies and presses used for trimming drop forgings; data for selecting proper size press given.

DURALUMIN

CORROSION. The Protection of Duralumin From Corrosion, W. Nelson. Aviation, vol. 21, no. 19, Nov. 8, 1926, pp. 795-799, 3 figs. Methods adopted for protection of duralumin structures from effects of corrosion; shows how use of this metal is made perfectly reliable and satisfactory in aircraft construction.

PROPERTIES. Duralumin, L. Aitchison. Flight (Aircraft Engr.), vol. 18, nos. 12, 17, 21, 25, 30, 39 and 43, Mar. 25, Apr. 29, May 27, June 24, July 29, Sept. 30 and Oct. 28, 1926, pp. 178a-178c, 260g-260i, 308g-308h, 362f-362h, 464a-464c, 636a-636c and 702d-702e. Reheating and heat treating of duralumin. Apr. 29: Tests to determine mechanical properties. May 27: Process of working after quenching; heating prior to quenching; working of salt baths. June 24: Corrosion and its causes. July 29: Hot working of duralumin; preparation of forging. Sept. 30: Discontinuities in duralumin. Oct. 28: Machining of forgings and drop forgings, and extruded and hammered duralumin bars; duralumin tubes; welding.

ELECTRIC FURNACES

ANNEALING. Electric Annealing Found Best by User, C. P. Yoder. Elec. World, vol. 88, no. 23, Dec. 4, 1926, pp. 1167-1171, 6 figs. Experiences of manufacturer who substituted electric annealing for oil-fired furnace under comparable conditions.

ANNEALING. Electric Annealing of Magnetic Materials for Telephone Apparatus, W. A. Timm. Am. Soc. Steel Treating—Trans., vol. 10, no. 5, Nov. 1926, pp. 782-799, 10 figs. Describes annealing equipment used by Western Electric Co. at Clinton Street shops up to 1909 and later at Hawthorne plant, in contrast to more recently installed electrical equipment; first named equipment was of coal-fired type, and second was of oil-fired type; in 1924 one electric recuperative furnace was installed at Hawthorne plant; it has been demonstrated that car-type recuperative annealing furnace is well adapted to type of work in question.

ANNEALING. Tests with Electric Annealing Furnaces (Versuche mit elektrischen Glühöfen), T. Stassinet. Stahl u. Eisen, vol. 46, no. 45, Nov. 11, 1926, pp. 1537-1547 and (discussion), 1547-1549, 18 figs. Results of tests show that proper dimensioning of fire-brick-wall thickness and insulation will bring about considerable saving in energy and great increase in efficiency; furnace built on this principle was subjected to thorough investigation, and it was shown that new type of electric annealing furnace can compete with most modern types of fuel-heated furnaces.

STEEL-HEATING. Electric Furnace for Heating Drill Steel, H. K. Fox. Elec. World, vol. 88, no. 21, Nov. 20, 1926, pp. 1074-1075, 2 figs. Oil displaced with successful arcless furnace on hydroelectric tunnel job; enumerates advantages over fuel-fired furnaces.

TOOL HARDENING. Lead-Bath Furnace Improves Tool Hardening, J. L. Faden. Elec. World, vol. 88, no. 20, Nov. 13, 1926, p. 1025, 1 fig. Installation of 23-kw. electric furnace for operation on 230-volt single-phase service in tool room of general service buildings of Edison Electric Illuminating Co., Boston, Mass.; outfit has capacity for heating about 150 lb. of steel per hour and consumes from 16 to 18 kw-hr. per hour in this service.

ELECTRIC WELDING

BUTT WELDING. Electric Fusion Welding Process (Das elektrische Abschmelzschweissverfahren), J. Sauer. Werkstattstechnik, vol. 20, no. 19, Oct. 1, 1926, pp. 579-585, 26 figs. Shows by means of examples on boiler tubes, crankshafts, camshafts, cutting tools, etc., that the butt-welding process has been improved to a point of giving absolutely safe welds; comparative data with fire welding, strength tests, etc.

GAS HOLDERS. A 1,000,000 cu. ft. Electrically-Welded Gasholder. Engineer, vol. 142, no. 3698, Nov. 26, 1926, pp. 586-587, 6 figs. Additional particulars concerning gas holder at Melbourne, Australia.

SEAM. Electric Seam Welding Applied to Sheet-Metal Work, F. W. Curtis. Am. Mach., vol. 65, no. 21, Nov. 18, 1926, pp. 833-835, 8 figs. Principles of seam-welding machine and procedure to follow in welding different

types of work; examples of welding operations; importance of cleaning; knurling rolls for scaling. See also description of machine in Iron Age, vol. 118, no. 21, Nov. 18, 1926, p. 413.

TORCHES. The Electric Torch, J. C. Lincoln. Am. Welding Soc.—Jl., vol. 5, no. 11, Nov. 1926, pp. 18-23, 2 figs. Apparatus developed in laboratory of Lincoln Electric Co.; experiments indicate that core of arc is blast from negative terminal, that current flows outside of blast, and that section of current across arc would be annulus and not a circle.

ELECTRIC WELDING, ARC

AUTOMATIC WELDER. General Electric Automatic Welder. Machy. (N. Y.), vol. 33, no. 4, Dec. 1926, p. 308, 1 fig. With new design of automatic arc welder, operator need only push button to start sequence of operations, weld being produced without any further effort or skill on his part. See also Iron Age, vol. 118, no. 23, Dec. 2, 1926, p. 1556, 2 figs.

AUTOMATIC WELDER. Westinghouse Automatic Arc Welder. Machy. (N. Y.), vol. 33, no. 4, Dec. 1926, pp. 309-310, 2 figs. Machine that automatically feeds welding wire used in metallic electrode welding, to work at any speed up to 3 ft. per minute; known as Auto-Arc machine.

CHARACTERISTICS AND APPLICATION. Electric Welding, Characteristics and Uses (La soudure électrique), M. A. Ménétrier. Electricité & Mécanique, nos. 12 and 13, May-June and July-Aug., 1926, pp. 1-14 and 18-33, 26 figs. Concludes from experiments that for plates 2 to 30 mm. thick, arc welding is best; for thinner plates resistance welding is best; automatic arc welding as developed by G.E.C. and used in United States.

HYDROGEN. Flames of Atomic Hydrogen, I. Langmuir. West Soc. Engrs.—Jl., vol. 31, no. 10, Oct. 1926, pp. 373-387, 7 figs. Review of author's researches leading up to new development in welding.

STRUCTURAL STEEL. Development of Arc Welding of Steel Structures, A. M. Candy. Eng. News-Rec., vol. 97, no. 17, Oct. 21, 1926, pp. 660-662, 3 figs. Some items of history since 1920; impact strength of welded joints; possibilities in design.

ELECTRIC WELDING, RESISTANCE

PRINCIPLES. Principles of Resistance Welding. Welding Engr., vol. 11, no. 11, Nov. 1926, pp. 37-38, 3 figs. Principle of electric spot, butt and seam welding; electrical features of welding machines.

FORGING

PRESSES. A Novel Electrically Operated Forging Press, A. Friederici. Eng. Progress, vol. 7, no. 11, Nov. 1926, pp. 309-311, 4 figs. Details of press manufactured by Kalk Machine Works, and comparison of this type with forging hammers and presses hitherto used.

FORGINGS

BRASS. Brass Forgings, O. J. Berger. Machy. (N. Y.), vol. 33, no. 4, Dec. 1926, pp. 299-300. Gives reasons for forgings replacing brass castings; finish and strength of forgings; comparison of machining costs; hot-pressed parts; dies for hot-pressed parts, drop and steam hammers and for trimming flash; importance of correct heating.

FURNACES, ANNEALING

WASTE-HEAT RECOVERY. Waste Gases from Annealing Furnaces, C. H. S. Tupholme. Iron & Coal Trades Rev., vol. 113, no. 3060, Oct. 22, 1926, p. 617, 2 figs. Waste-heat boiler was installed by Sulzer Bros. at works of Swiss Trading Co., Neuhausen, for recovery of heat; its use for raising high-pressure steam.

FURNACES, GAS

BABBITT METAL, FOR. Gas Furnace for Babbitt Metal, C. C. Hermann. Brass World, vol. 22, no. 11, Nov. 1926, p. 354. Factors influencing selection of gas over other fuels for new furnace installed for melting babbitt metal.

NON-FERROUS METALS, FOR. Gas in Non-Ferrous Metal Industry, R. S. Wile. Am. Gas Jl., vol. 125, no. 25, Nov. 20, 1926, pp. 605-606. Its use is compared with electricity; describes various types; recuperative gas furnace for brass melting, etc.; gas for galvanizing, and in making storage batteries.

FURNACES, HEAT-TREATING

ELECTRIC. Electrically-Heated Bath Furnaces, C. H. Carpenter. Indus. Engr., vol. 84, no. 11, Nov. 1926, pp. 508-512, 5 figs. Types commonly used in heat treatment of metal parts, and operating advantages which they offer.

ROTARY-RETORT. Heat Treatment of Conveyor Parts in Rotary Retort Furnaces, F. S. O'Neill. Fuels and Furnaces, vol. 4, no. 12, Dec. 1926, pp. 1451-1452 and 1468, 2 figs. Rotary-retort furnaces heated with by-product coke oven gas used in annealing, hardening, and carburizing of parts of various sizes.

FURNACES, HEATING

BILLET-HEATING. The Bohler Billet-Heating Furnace. Iron & Coal Trades Rev., vol. 113, no. 3062, Nov. 5, 1926, p. 691, 2 figs. Furnace developed by engineer of French steel works consists of vertical heating chamber of rectangular section, in which billets are stacked; gas enters at upper part of chamber and passes downwards through pile of billets; cold billets are introduced at bottom of pile, and heated ones withdrawn from top of pile.

GAS-FIRED. Town Gas Fired Plate and Bar Re-Heating Furnace. Gas Jl., vol. 176, no. 3311, Nov. 3, 1926, p. 290, 2 figs. Believed to be the largest furnace in England fired by means of coal gas; advantages derived from utilization of city gas when properly applied.

HEAT TRANSMISSION IN. Heat Transmission in Ingot-Heating Furnaces (Neuere Erkenntnisse auf dem Gebiete des Wärmeübergangs in Stossöfen), H. Netz. Stahl u. Eisen, vol. 46, no. 46, Nov. 18, 1926, pp. 1592-1594, 2 figs. Results of investigations on a coal-fired furnace to determine heat-transmission coefficients for transfer of heat from gas to ingot; conditions influencing heat transmission.

FURNACES, INDUSTRIAL

DESIGN. General Principles of Furnace Construction and Design, W. Trinks. Gas Age-Rec., vol. 58, nos. 13 and 14, Sept. 25 and Oct. 2, 1926, pp. 419-422 and 453-456,

16 figs. Discusses types and features of design; points out that heating capacity of furnace is based upon (1) temperature equalization in charge (2) heat transfer to charge (3) liberation of generation of heat.

HARDNESS

BRINELL TEST. Limits of Application of Brinell Hardness Test (Anwendbarkeitsgrenzen der Brinellschen Kugeldruckprobe), P. W. Döhmer. Motorwagen, vol. 29, no. 24, Aug. 31, 1926, pp. 556-557. In technical publications there have appeared figures indicating Brinell hardness up to 1000; such hardness, for instance, was indicated for nitration case-hardening process of Krupp; in case of hardness figures of this magnitude, Brinell ball itself deforms excessively; it is likely that no hardness figure exceeding 500 Brinell is reputable; this would correspond to tensile strength of 350,000 lb. per sq. in.; for greater hardness, scratch methods or Shore or Herbert devices should be used.

HEAT TREATMENT

ELECTRIC. Manufacturing by Electric Heat, W. S. Scott. Elec. Jl., vol. 23, no. 11, Nov. 1926, pp. 548-555, 9 figs. Deals with all heating processes in general use; general advantages of using electric heat; common products so heat treated; electrical equipment available for correctly and satisfactorily meeting application.

NICKEL. Latest Methods of Heat Treating Are Applied to Nickel and its Alloys, F. M. Manker. Iron Trade Rev., vol. 79, no. 22, Nov. 25, 1926, pp. 1347-1350, 4 figs. Equipment and practice of International Nickel Co., at Huntington, W. Va.; new type of continuous open annealing or normalizing furnace is under construction, and designed to take place of 6 box-annealing furnaces without any increase in gas consumption per pound of material heated; practically all of furnaces are fired by gas and were designed, manufactured and installed by Surface Combustion Co., New York.

IRON

COMMERCIALLY PURE. Pure Metals in Electrical Engineering, L. P. Sidney. Elecn., vol. 97, no. 2530, Nov. 26, 1926, pp. 608-609 and 618, 5 figs. Distinction between chemical and commercial purity; method of production; properties of "Armco" iron; some essentials.

FERROALLOY ADDITIONS TO CHARGE. Simplify Ferroalloy Additions, R. S. Kerns. Foundry, vol. 54, no. 13, July 1, 1926, pp. 514-516, 1 chart. Presents series of curves or chart which gives required weight of alloy addition to any weight of charge when weight of charge, percentage of alloy in ferroalloy, and number of points alloy is to be raised are known. See also Forging—Stamping—Heat Treating, vol. 12, no. 11, Nov. 1926, pp. 425-427.

PLASTIC DEFORMATION. The Plastic Deformation of Iron. Metallurgist (Supp. to Engineer, vol. 142, no. 3698), Nov. 26, 1926, pp. 161-162. Discusses formation of slip bands under strain; results of research.

IRON ALLOYS

CHROMIUM-IRON-CARBON. Nature of the Chromium-Iron-Carbon Diagram, M. A. Grossmann. Am. Inst. Min. & Met. Engrs.—Trans., no. 1612-C, Dec. 1926, 17 pp., 18 figs. Consideration of somewhat radical modifications in iron-carbon diagram which are result of presence of notable amounts of alloying elements.

IRON-MOLYBDENUM. The Iron-Molybdenum System, W. P. Sykes. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 839-870 and (discussion) 870-871 and 1035, 46 figs. Describes carbon-free alloys of iron and molybdenum and includes equilibrium diagram of this system as determined from fusion temperatures, heat treatments and study of accompanying microstructures; temperature-solubility relations make possible development of secondary hardness by aging supersaturated solid solution at 1112 to 1290 deg. Fahr.; this hardness is equal to that of high-speed steel and persists at temperatures considerably higher.

NICKEL-IRON. Nickel-Iron Alloys, W. T. Griffiths. Elecn., vol. 97, no. 2530, Nov. 26, 1926, pp. 612-613 and 618, 5 figs. Remarkable magnetic properties; high initial permeability and low hysteresis loss; their importance in submarine telegraphy.

SILICON DETECTION. A Specific Etching Medium for Detecting Silicon in Iron by Etching (Ein spezifisches Aetzmittel für Silizium in Eisen), P. Oberhoffer. Stahl u. Eisen, vol. 46, no. 35, Sept. 2, 1926, pp. 1191-1192, 5 figs.; also translated abstract in Iron Age, vol. 118, no. 24, Dec. 9, 1926, p. 1618, 2 figs. Results of experiments using iodine as etching reagent for silicon in iron; solution found best is alcoholic one, 1:10, of 0.1 per cent normal iodine with etching time of 5 to 15 min.; effect of other elements in presence of silicon.

IRON CASTINGS

GRATE BARS. Results of Investigations of Grate Bars (Ergebnisse von Untersuchungen an Roststäben), Kühnel. Giesserei, vol. 13, no. 43, Oct. 22, 1926, pp. 809-815 and (discussion) 815-818, 16 figs. Review of recent large-scale investigations; results of author's tests on bars with varying phosphorus content; sulphur enrichment; main zone of destruction lies only in path of combustion and extends over a depth not exceeding 1 cm.

IRON METALLURGY

PROGRESS. The New Year's Progress in Ferrous Metallurgy. Mech. Eng., vol. 48, no. 12, Dec. 1926, pp. 1443-1448, 3 figs. Presents advances in metallurgy of ferrous materials that have taken place since summer of 1925; deals with martensite, delta iron, impact tests on nickel-chromium steels, macroscopic examination of iron and steel, etching reagents, ultra-violet metallurgy, X-Ray photography, chromizing, method of observing flaws in metal surfaces, dilatometric method of heat treatment, carburization, Maurer carbon-silicon diagram of cast iron, malleable cast iron, electric silicon steel, fatigue failure of metals, etc.

MALLEABLE IRON

ANNEALING. Annealing Malleable Castings in a Continuous Tunnel Furnace, W. N. Robinson. Fuels and Furnaces, vol. 4, no. 12, Dec. 1926, pp. 1473-1475 and 1478, 3 figs. Semi-muffle furnace of tunnel-kiln type heated by producer gas has productive capacity of 16 tons per 24-hour day on 120-hour annealing cycle.

MALLEABLE IRON

HEAT TREATMENT. The Malleableizing Heat Treatment, H. A. Schwartz. Forging—

Stamping—Heat Treating, vol. 12, no. 11, Nov. 1926, pp. 413-415. Author discusses metallurgical and manufacturing limitations under which heat treatment of malleable castings is carried out.

MALLEABLEIZING KILN. A Continuous Malleableizing Kiln, G. Blakney. Am. Gas Assn. Monthly, vol. 8, no. 12, Dec. 1926, pp. 755-756 and 759-760. Development of tunnel type of continuous oven, through which pots of castings are passed in regular sequence; outstanding feature is design of tunnel, which is open full length on both sides from bottom of kiln; another characteristic is semi-muffle feature.

WHITE-HEART VS. BLACK-HEART. A Comparison of Whiteheart and Blackheart Malleable Cast Irons, A. E. Peace. Foundry Trade Jl., vol. 34, no. 536, Nov. 25, 1926, pp. 460-462. Essential difference in two materials is due to pig iron used; melting and casting; annealing and straightening; structure and physical properties; magnetic properties; applications.

MANGANESE STEEL

CHARACTERISTICS. Characteristics of Alloy Steels—Manganese Steel. Am. Mach., vol. 65, no. 24, Dec. 9, 1926, p. 963. Effect of manganese; forging and casting; heat treating. Reference-book sheet.

METAL DRAWING

PLASTIC BEHAVIOR OF METAL. The Plastic Behavior of Metal in Drawing, C. L. Eksergian. Am. Soc. Mech. Engrs.—Advance Paper, for mtg. Dec. 6-9, 1926, 35 pp., 21 figs. Author seeks to foster development of analysis to drawing as aid to subsequent development; outlines manner of working metal with reference to its state and behavior in comparison with that found in drawing; survey of conditions observed in forming of stamping.

METALLOGRAPHY

NON-FERROUS. Non-Ferrous Metallography, J. S. G. Primrose. Foundry Trade Jl., vol. 33, nos. 513 and 514, June 17 and 24, 1926, pp. 453-456 and 486-490, 26 figs. Results of experience in research into new properties, pathological investigation of failures, and examination to ensure compliance with rigid specifications; apparatus and illumination; modifications of Le Chatelier apparatus; discusses various types of microstructure including brasses, bronzes, aluminum, nickel and silver alloys, and copper. See also Metal Industry (Lond.), vol. 28, nos. 25 and 26, June 18 and 25, 1926, pp. 569-573 and 592-594, 24 figs.

METALLOGRAPHY

WELDERS, FOR. Metallography for the Welder, J. B. Green. Welding Engr., vol. 11, no. 11, Nov. 1926, pp. 29-32, 7 figs. Points out that familiarity with this science will enable welder to understand significant features of scientific papers on subject; points out in elementary way how photomicrograph is taken, what it represents and explains briefly meaning of a few of commoner technical terms often employed.

METALLURGY

RAILWAY, GERMANY. Railway Metallurgy in Germany. Ry. Engr., vol. 47, no. 562, Nov. 1926, p. 399. High-silicon steel for railway springs and some tests of railway drawbar hooks.

METALS

FATIGUE. The Mechanism of the Fatigue Failure of Metals, H. F. Moore. Franklin Inst.—Jl., vol. 202, no. 5, Nov. 1926, pp. 547-568, 13 figs. Demonstrates what happens when metal fractures under repeated stress; in considering fatigue of metals under repeated stress, it becomes necessary to recognize that ordinary formulas for stress and strain are strictly true only for ideal metal; actual metals are not ideal and hence ordinary formulas for stress and strain have high degree of precision only if large number of crystalline grains are considered together; actual metals do not develop strengths under load so great as would be expected from computed cohesion of their atoms; under repeated stress their strength is still smaller.

DISRUPTIVE STRENGTH. Determination of Disruptive Strength (Bestimmung der Reissfestigkeit aus der gleichmässigen Dehnung), P. Ludwik. Zeit. für Metallkunde, vol. 18, no 9, Sept. 1926, pp. 269-272, 5 figs. Presents simple rule for calculation of rupture strength in ordinary tensile test from tensile strength, rupture contraction and uniform expansion.

HARDENING. The Hardening of Metals by Dispersed Constituents Precipitated from Solid Solutions, R. S. Archer. Am. Soc. Steel Treating—Trans., vol. 10, no. 5, Nov. 1926, pp. 718-747 and (discussion) 747-757, 9 figs. Metals may be effectively hardened by highly dispersed particles within grains; typical process of hardening by this means consists in solution heat treatment at relatively high temperature followed by rapid cooling into region of supersaturation, then by precipitation treatment or aging to permit formation of very fine precipitate; examples of this type of hardening and generalizations regarding theory of process.

LATENT HEAT OF FUSION. The Latent Heat of Fusion of Some Metals, J. H. Awbery and E. Griffiths. Physical Soc. of London—Proceedings, vol. 38, Aug. 15, 1926, pp. 378-398, 4 figs. Latent heats of number of commoner metals have been measured by determining total heat of liquid and solid from series of initial high temperatures; results for latent heat for aluminum, antimony, bismuth, lead, magnesium, tin and zinc; values for specific heats up to melting point, obtained by differentiation of temperature-total heat curves.

LIMITING FLOW TENSIONS. Tension Conditions at the Flow Limits (Condition of Plasticity), F. Schleicher. Zeit. für angewandte Mathematik u. Mechanik, vol. 6, no. 3, June 1926, pp. 199-216, 12 figs. Critical survey of hypotheses previously proposed for flow state; these are shown for most part not to be in accord with actual conditions; author submits new hypothesis which is in better agreement with latest data of v. Karman, Böker and Lode than that of Mohr, while supplying explanation in cases where latter is invalid; advantages are also claimed for difficulties which arise with building materials having different limiting flow tensions.

PHYSICAL PROPERTIES. Physical Methods of Studying Properties of Metals (I metodi fisici nello studio delle proprieta dei metalli), W. Del Regno. Nuovo Cimento, vol. 3, no. 6, June, 1926, pp. 109-117. Concludes that elementary structure of principal metals

and alloys can be determined by X-rays; but photoelectricity and thermal and thermionic emissions will play an important part in high-temperature research.

PHYSICAL PROPERTIES. Physical Properties of Engineering Materials. Power Engr., vol. 21, no. 248, Nov. 1926, pp. 426-428, 2 figs. Deals with tin and nickel.

PLASTIC DEFORMATION. Plastic Deformation of Metals, J. T. Norton and B. E. Warren. Am. Inst. Min. & Met. Engrs.—Trans., no. 1610-E, Dec. 1926, 17 pp., 20 figs. Notes of Nature and results of plastic deformation produced in cold working of metals; plastic deformation in face-centered cubic metal takes place by slip; many processes involved in cold working of metal give rise to same effects as those which occur by simple processes of elongation and directional rolling.

MOLDS

INGOT. Electric Hot Top Ingots. Metal Industry (Lond.), vol. 29, no. 22, Nov. 26, 1926, pp. 515-516, 1 fig. Account of experiments carried out using electrical method of heating tops of ingots of nickel and monel metal as cast in International Nickel Co.'s works at Huntington; casting and feeding; electrode consumption.

NEEDLES

MANUFACTURE. Development of Needle Making, E. R. Miner. Wire, vol. 1, no. 8, Dec. 1926, pp. 267-269 and 284-285, 5 figs. Details of cutting, straightening, pointing, stamping, punching, tempering and scouring.

NICKEL

MAGNETIC HYSTERESIS. Parallelism between the Phenomena of Magnetostriction and Magnetic Hysteresis in Nickel (Ueber den Parallelismus zwischen den Erscheinungen der Magnetostriktion und der magnetischen Hysteresis in Nickel), B. Wwedensky and J. Simanow. Zeit. für Physik, vol. 38, no. 3, July 28, 1926, p. 202-214, 10 figs. Nickel wire of 0.5 mm. diameter was suspended from lever, passed through vertical core of electromagnet, and stretched by a weight; striction curves as function of applied tensile stress follow same course as hysteresis curves, and it is concluded that they are related; there is no simple parallelism between magnetostriction and magnetization, remanence, coercive force.

NICKEL STEEL

PHYSICAL PROPERTIES. Physical Properties of Nickel and Nickel-Chromium Steels. International Nickel Co.—Nickel Steel Data and Applications, no. 9, 16 pp., 14 figs. Presents physical properties of nickel and nickel-chromium steels by means of average curves and tables of maximum and minimum values in endeavor to provide reliable data which can be used as basis for engineering calculations.

NON-FERROUS METALS

INDUSTRIAL UTILIZATION. Non-Ferrous Metals (Die moderne Forschung auf dem Gebiete der Nichteisenmetalle, insbesondere der Leichtmetalle), A. Petersen. Zeit. für angewandte Chemie, vol. 39, no. 40, Oct. 7, 1926, pp. 1170-1171. Review of progress in industrial utilization of light metals; in addition to aluminum and magnesium, lithium is being found very useful for increasing strength of other metals; aluminum and its alloys are particularly useful in automotive field.

PROPERTIES. Metals and Their Properties, T. Newton. Sheet Metal Worker, vol. 17, no. 22, Dec. 3, 1926, pp. 876-877. Information on composition and characteristics of non-ferrous alloys, including pewter, German silver, phosphor-tin, also hard solders and brazing spelters.

REFINING. The Chemist in Non-Ferrous Metal Refining, F. C. Robinson. Chem. Age, vol. 15, no. 387, Nov. 27, 1926, pp. 518-519. Deals with position of chemist in non-ferrous metallurgical industries. (Abstract) Streatfeild Memorial Lecture.

OPEN-HEARTH FURNACES

FORD PLANT, DETROIT. Ford Open-Hearth Plant Unique, F. L. Prentiss. Iron Age, vol. 118, no. 23, Dec. 2, 1926, pp. 1539-1545, 13 figs. New open-hearth unit at Ford plant contains number of interesting features, both in arrangement and practice, including small size of ingots made, method of pouring and stripping ingots, way slag is handled and arrangement of stockyard, which is on ground level, or same level as pouring side, instead of having usual high line on which scrap is brought in on tracks on level with charging side; there are four 100-ton basic furnaces of tilting type.

HEAT BALANCE. Representation of Heat Balances with Regard to Heat-Drop Coefficient (Die Darstellung von Wärmebilanzen unter Berücksichtigung des Wärmegefällewertes), H. Bansen. Stahl u. Eisen, vol. 46, no. 45, Nov. 11, 1926, pp. 1558-1560, 2 figs. Disadvantages of method heretofore employed; describes new arrangement of Sankey diagram and points out its advantages; example of application to open-hearth furnaces.

PROCESSES. The Open-Hearth Process, H. M. Boylston. Fuels and Furnaces, vol. 4, no. 12, Dec. 1926, pp. 1423-1432, 6 figs. Acid and basic open-hearth processes; charge, fuels, melt, tap slag, etc.; equipment; various processes for making steel; recent improvements in furnace design.

OXYACETYLENE WELDING

AUTOMOBILE-ENGINE CYLINDERS. The Welding of Cast Iron Internal Combustion Engine Cylinders, H. A. Horn. Am. Soc. Naval Engrs.—Jl., vol. 38, no. 4, Nov. 1926, pp. 904-911, 6 figs. Deals with welding of automobile-engine cylinders; enumerates principal casualties to automobile cylinders and methods of repairing them by oxyacetylene welding. Translated from German.

BRONZE WELDING. Bronze-Welding Foundry Flasks. Oxy-Acetylene Tips, vol. 5, no. 5, Dec. 1926, pp. 84-86, 5 figs. Leading foundry saves $60,000 annually by this method of reclamation.

DEVELOPMENTS. Oxy-Acetylene Welding and Cutting, C. S. Milne. Machy. Market, nos. 1333, 1334, 1335, 1336 and 1339, May 21, 28, June 4, 11 and July 2, 1926, pp. 25-26, 21-22, 23-24, 21-22 and 23-24, 27 figs. Review of present position. Paper read before Brit. Acetylene & Welding Assn.

MANUFACTURING BASIS. Welding on a Manufacturing Basis, Machy. (Lond.), vol. 29, no. 735, Nov. 11, 1926, pp. 174-176, 6 figs. Costing of oxyacetylene welding; estimating and rate fixing; testing of welded work; hints concerning running and supervision of welding department.

ROOF TRUSSES. Tests of Welded Trusses and a New Truss Joint, H. H. Moss. Eng. News-Rec., vol. 97, no. 18, Oct. 28, 1926, pp. 712-713, 3 figs. Roof trusses 40 feet in span and 10 feet deep using new insert plate joint tested under three times design load; results of tests conducted at Buffalo shops of Linde Air Products Co.

SINGLE-VEE WELDS. Ultimate Strength of Single Vee Welds, E. E. Thum. Am. Welding Soc.—Jl., vol. 5, no. 11, Nov. 1926, pp. 23-26, 2 figs. Results of tests made by Union Carbide and Carbon Research Laboratories, showing measure of reliability of oxy-acetylene welding when done by men selected with reasonable care, and working under principles of procedure control.

PYROMETERS

Optical. Measuring High Temperatures and the Improved Filament Pyrometer (Die Messung hoher Temperaturen und das verbesserte elektrische Glühfaden-Pyrometer), M. Foerster. Wärme-u. Kälte-Technik, vol. 28, no. 22, Nov. 3, 1926, pp. 259-262, 8 figs. Discusses development of optical radiation pyrometers; describes Halborn-Kurlbaum, Fery and Siemens types; measuring temperatures of up to 2000-3000 deg. Cent.

RAILS

JOINTS, WELDED. A New Rail Joint, W. Spraragen. Am. Welding Soc.—Jl., vol. 5, no. 11, Nov. 1926, pp. 8-9, 1 fig. Author describes new form of joint particularly adapted to metal arc welding; it is really nothing more than straight butt joint made in rail without addition of fishplates and with or without addition of baseplate to give additional strength.

JOINTS, WELDED. Rail Joints and Thermit Welding (Gleiswirtschaft, Schienenstossfrage und Thermitschweissung), R. Hanker. Zeit. des Oster. Ingenieur- u. Architekten-Vereines, vol. 78, nos. 43-44 and 45-46, Oct. 29, and Nov. 12, 1926, pp. 433-437 and 447-451, 16 figs. Describes thermit welding process by Elektro-Thermit Co. of Berlin, in which one part aluminum and three parts iron oxide are used, producing temperature of about 3000 deg. Cent.; details of apparatus used; advantages and disadvantages.

ROLLING MILLS

BAR MILLS. Inspection Trip Cambria Works—Bethlehem Steel Company, Johnstown, Pennsylvania. Iron & Steel Engr., vol. 3, no. 9, Sept. 1926, pp. 422-426, 11 figs. Four new bar mills acknowledged to be among most modern rolling mills of present day and representing latest developments in mechanical, combustion, safety and electrical arts.

BAR MILLS. New Rolling Mills—Gautier Plant, Cambria Works, Bethlehem Steel Co., Johnstown, Pa., R. H. Stevens. Iron & Steel Engr., vol. 3, no. 10, Oct. 1926, pp. 446-452, 1 fig. Four new bar mills have been installed and power house for furnishing additional electric current for same; new mills were designed for use of approximately 30 ft. billets; 14-in. mill is designed to roll channels, beams, angles, automobile rim sections, light rails and flats; 13-in. mill is used for rolling rounds, squares, flats and concrete bars in larger sizes; 10-in. mill is more of tonnage unit; 9-in mill is jobbing unit designed to roll miscellaneous shapes.

BLOOMING MILLS. Continuous 42-In. Blooming Mill. Iron Age, vol. 118, no. 24, Dec. 9, 1926, pp. 1621-1625 and 1671, 8 figs. Ford plant, using 1500-lb. ingots, expected to produce 100,000 tons per month; unique housings and manipulators.

ELECTRIC DRIVE. Electricity in Steel Manufacture. Elec. Engr. Australia & New Zealand, vol. 3, no. 7, Oct. 15, 1926, pp. 249-250, 1 fig. Details of electrical equipment of Victoria Iron Rolling Co. in Australia; scrap is melted and refined in 7-ton electric steel furnace of Heroult type, which has melted heats up to 10 tons; forgings up to 16½ tons weight are made on 500-ton Davy steam-hydraulic press; there are two rolling mills for manufacturing bar, rod and special sections; mill is driven by 1000-hp. Metropolitan Vickers 6600-volt, three-phase induction motor.

ELECTRIC DRIVE. Rolling Mill Electrification. Elecn., vol. 97, no. 2530, Nov. 26, 1926, p. 616, 1 fig. Break away from traditional practice; speed-control arrangements; easy and rapid reversal possible; low initial costs.

HOT ROLLING. Recent Improvements in Hot Rolling Mills (Les récents perfectionnements apportés aux laminoirs a chaud), P. Brenier. Technique Moderne, vol. 18, no. 19, Oct. 1, 1926, pp. 577-585, 37 figs. Discusses recent progress in blooming mills two- and three-high mills; merchant, iron-sheet rolling and wire mills, etc.; their operation; auxiliaries.

I-BEAMS. Experimental Investigations on the Flow of Material in the Rolling of I-Beams (Experimentelle Untersuchungen des Materialflusses beim Walzen von Trägern), N. Metz. Stahl u. Eisen, vol. 46, no. 46, Nov. 18, 1926, pp. 1577-1582, 36 figs. partly on supp. plates. Method of making deformations visible; by inserting screws in different parts of material to be rolled, it is possible to follow movement of material in open and closed passes; results afford explanation for high pressure and power required in rolling of beams, as compared with flat iron.

INGOT-HANDLING EQUIPMENT. Steel Mill Ingot Handling Equipment, P. McShane. Elec. Jl., vol. 23, no. 11, Nov. 1926, pp. 559-561, 1 fig. Deals with that portion of equipment which is subject to considerable variation in form and arrangement.

LUBRICATION. New Methods of Lubricating Steel-Mill Machinery, C. H. Bromley. Mech. Eng., vol. 48, no. 11a, Mid-Nov. 1926, pp. 1344-1346, 2 figs. Requirements in lubricating oils; characteristics of lubricants suitable for gears and journals; gravity- and pressure-type lubricating systems; rates at which oil should be supplied, etc.

MERCHANT MILL. Schedules 10-Inch Merchant Mill, J. D. Knox. Iron Trade Rev., vol. 79, no. 21, Nov. 18, 1926, pp. 1297-1299 and 1304, 4 figs. Mill built by Morgan Construction Co. is designed to roll rounds from ¼ in. to 1 in. or equivalent sizes of squares and flats, and strip from ⅞ in. to 2½ in. wide with minimum thickness of 0.04 in., installed in plant of Corrigan, McKinney Steel Co., Cleveland.

MOTOR CONTROL. Full Reverse A. C. 2-Speed Mill Controller, E. G. Peterson. Iron & Steel Engr., vol. 3, no. 11, Nov. 1926, pp. 481-482, 4 figs. Describes control panel used with motors driving sliding frame saws in modern steel mill, rolling large shapes, such as I-beams, channels, etc.; controllers are arranged to provide automatic current-limit ac-

celeration by means of three-phase series relays connected in motor secondary.

SLAG

DESULPHURIZATION. Desulphurization, E. J. Lowry. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 906-936 and (discussion) 936-940. Discusses slags, fluxes and desulphurizers; fluxes have definite lines which divide them into classes which produce (1) proper slags; (2) proper slags combined with efficient desulphurization; and (3) improper slags; account of experiences, results and conclusions which may be of interest and value to future investigators.

STEEL

CRYSTALLIZATION. Dendritic Crystallization and Grain Formation in Steels, V. N. Krivobok. Am. Soc. Steel Treating—Trans., vol. 10, no. 5, Nov. 1926, pp. 758-781, 27 figs. Gives secondary transformations which take place in steels in solid state; discusses generally accepted ideas of mechanism of crystallization; concludes that dendritic segregation is not sole cause of defective steel and pronounced dendritic structure is not sufficient cause for rejection of steel; by means of photomicrographs, author shows microstructure of dendritic branches found in steels of different composition and non-metallic inclusions ordinarily found in steels and those found in steels of large and well-developed dendritic structures; results of various heat treatments, quenching, heating and cooling upon microstructure.

CYANIDE BRITTLENESS. Cyanide Brittleness, V. E. Hillman and E. D. Clark. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 954-962 and (discussion) 962-964, 11 figs. Points out that popular misconception in reference to brittleness of core has been dispelled; discussion of mechanism of rupture with case intact and case removed; results of investigation by curves and photographic evidence.

EMBRITTLEMENT. Embrittlement of Steel, A. G. Christie. Mech. Eng., vol. 48, no. 11a, Mid-Nov. 1926, pp. 1368-1372. Review of investigations and opinions on embrittlement of steel used in boilers; progress report of Sub-Committee no. 6 of Joint Research Committee on Boiler Feedwater Studies.

GAGES, WEAR OF. Wear of Steels with Particular Reference to Plug Gages, H. J. French and H. K. Herschman. Am. Soc. Steel Treating—Trans., vol. 10, no. 5, Nov. 1926, pp. 683-712 and (discussion) 713-717 and 813, 10 figs. New gage wear-testing machine is described and results obtained by its use are discussed for wet sliding friction of metal on metal and wear by abrasives; comparisons of service-wear tests at different plants with results obtained in laboratory with gage-wear tester; data presented to show that file hardness is not a criterion of good wear resistance of gages; chromium-plated steel gages are likewise compared with gages made from heat-treated steels of customary types.

HARDENING. The Hardening of Steel (Ueber die Härtung des Stahles), H. Hanemann. Stahl u. Eisen, vol. 46, no. 46, Nov. 18, 1926, pp. 1585-1587, 1 fig. Compares Maurer hardening theory with Hanemann-Schrader theory; difference between the two consists in conception of position of carbon atoms in martensite.

HIGH-CARBON. The Construction of Steel and Cast Iron, F. T. Sisco. Am. Soc. Steel Treating—Trans., vol. 10, no. 5, Nov. 1926, pp. 800-813, 3 figs. Deals with structure of high-carbon steels, and structural changes in these steels when they are heated and cooled through transformation ranges; methods for calculation of amount of various structural constituents present in hypoeutectoid, eutectoid, and hypereutectoid steels.

PERMANENT MAGNETS, FOR. The Magnetic Stability of Permanent Magnets, R. C. Gray. London, Edinburgh and Dublin Philosophical Mag., vol. 2, no. 9, Sept. 1926, pp. 521-529, 7 figs. Process of aging, either by heat treatment, vibration, or partial demagnetization, or by all of these, represents attempt to bring magnet into its final stable state in few hours instead of months; author gives effect of each of these treatments on magnetic stability of magnet.

SEGREGATION. Controlling Segregation in Steel, H. D. Hibbard. Iron Age, vol. 118, no. 23, Dec. 2, 1926, pp. 1546-1547. Main factors to be considered; segregation defined nd its progress described in killed, partly killed, and rimming steel.

TEMPER BRITTLENESS. Temper Brittleness of Steels (La fragilité de revenu des aciers), L. Guillet and M. Ballay. Revue de Métallurgie, vol. 23, nos. 9 and 10, Sept. and Oct. 1926, pp. 507-520 and 605-617, 21 figs. Concludes that chemical analysis does not indicate with exactitude degree of susceptibility of metal to temper brittleness, but investigation shows that in nearly all cases it is possible to prevent temper brittleness by a simple treatment even if a susceptible steel is employed; after a steel has become brittle, regeneration can be effected by heating above 600 deg. Cent. and cooling rapidly; theories of temper brittleness. Bibliography.

STEEL CASTINGS

FATIGUE STRENGTH. Tests of the Fatigue Strength of Cast Steel, H. F. Moore. Univ. of Illinois Bul., vol. 23, no. 44, July 6, 1926, pp. 5-20, 37 figs. Chemical composition and heat treatment of steels; test specimens and methods of testing; test data and results; report of investigation conducted by Engineering Experiment Station of University of Illinois in coöperation with American Steel Foundries.

MACHINE TOOLS, FOR. Lighter Metal for Machine Tools, J. W. Bolton. Iron Age, vol. 118, no. 24, Dec. 9, 1926, pp. 1615-1618, 5 figs. Discusses what can be done to help quality of tool by raising physical standards of casting; advocates use of steel and alloy steel; suggests that use of fine-grained iron of nearly pearlitic matrix is ideal material for machine-tool construction.

STEEL, HEAT TREATMENT OF

ANNEALING. The Transformations in Hardened Steel Due to Annealing (Die Umwandlungen des gehärteten Stahles beim Anlassen), H. Hanemann and L. Traeger. Stahl u. Eisen, vol. 46, no. 44, Nov. 4, 1926, pp. 1508-1514, 9 figs. Points out that annealing temperature of only 100 deg. has a decided influence on hardened steel; when annealed for duration of 14 hours, hardness of a carbon steel is completely changed by heat of boiling water; for tool steel, annealing temperature of 200 to 300 deg. is customary; if it is desired to make a hardened steel volumetrically constant for temperatures above 280 deg., an

annealing temperature of 400 deg. is necessary.

CHAINS. Heat Treatment of Chains. Mech. World, vol. 80, no. 2079, Nov. 5, 1926, p. 363. Object is removal or partial removal of hardening and embrittlement produced by strains and shocks to which chains are subjected in practice; studies effect of low-temperature annealing, (650 to 760 deg. Cent.), and normalizing, upon mechanical properties of chains which have been subjected to varying degrees of plastic strain.

ELECTRIC. Electric Heat Treatment of Steel, N. P. Barfield. Elecn., vol. 97, no. 2530, Nov. 26, 1926, pp. 614-615, 3 figs. Improvements in furnaces; classification of equipment; automatic temperature control

FACTS AND PRINCIPLES. Facts and Principles Concerning Steel and Heat Treatment, H. B. Knowlton. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 971-985, 4 figs. Properties and uses of alloy steels other than tool steels, in general; discussion of various types of nickel steels.

MECHANICAL PROPERTIES, INFLUENCE ON. The Effects of Heat Treatments Upon the Mechanical Properties of Steels, F. W. Duesing. Mech. World, vol. 80, no. 2078, Oct. 29, 1926, p. 345. Results of tests carried out by author on eight qualities of mild steel. Brief abstract translated from German.

OIL-WELL SUCKER RODS. Heat Treatment as Now Applied to Sucker-Rods. Petroleum Times, vol. 16, no. 411, Nov. 27, 1926, p. 950. Special method of treatment used by D. & B. Pump & Supply Co., as result of which weak, pure-iron constituent has been very largely eliminated from steel, thereby lessening tendency to fatigue failure and ultimate strength of steel has been greatly increased, but without any increase in brittleness.

STEEL, HIGH-SPEED

CHARACTERISTICS. Characteristics of Alloy Steels—High-Speed Steel. Am. Mach., vol. 65, no. 23, Dec. 2, 1926, p. 921. A.S. T.M. standard permissible variations in composition of high-speed steel; standard tolerances in dimensions of high-speed steel stock. Reference-book sheet.

STEEL INDUSTRY

ELECTRICAL HAZARDS. Electrical Hazards in the Steel Industry, F. W. Cramer. Iron & Steel Engr., vol. 3, no. 11, Nov. 1926, pp. 463-465. Calls attention to electrical hazards and means of eliminating them.

STEEL MANUFACTURE

BESSEMER PROCESS. The Bessemer Process, H. M. Boylston. Fuels & Furnaces, vol. 4, no. 11, Nov. 1926, pp. 1299-1306, 6 figs. Describes acid and basic processes and chemical reactions involved; design, construction and operation of converter and mixers; relining of converters and replacing bottoms. Abstract of study from author's treatise on Iron and Steel.

IMPROVEMENT OF METHODS. The Quality of Steel and Its Relations to Production Method (Ueber Stahlqualitäten und ihre Beziehungen zu den Herstellverfahren), P. Goerens. Zeit. des Vereines deutscher Ingenieure, vol. 70, nos. 33, 34 and 36, Aug. 14, 21 and Sept. 4, 1926, pp. 1093-1099, 1129-1136 and 1194-1198, 31 figs. What is understood by quality; non-metallic inclusions in steel, their detection and significance; present methods of manufacturing steel, their advantages and disadvantages; prospects of improving methods; necessity of close coöperation between consumers and producers.

STEEL WORKS

RENEWAL PARTS. Renewal Parts and Renewal Part Records, W. S. Shirk. Iron and Steel Engr., vol. 3, no. 11, Nov. 1926, pp. 466-470, 10 figs. In order to properly serve industrial plants with renewal-part requirements it is necessary that manufacturer be ready at any time to furnish from stock or manufacture part that is required; renewal-part record that is most desired by industrial plants is system which does not involve excessive number of cards and at same time is complete in every respect in order that each and every part can be properly identified; card system to be used in storeroom.

STRUCTURAL STEEL

BRIDGES, FOR. Experiences with High Grade Steel St 48 and Silicon Bridge Steel (Erfahrungen mit hochwertigem Baustahle St 48 und Silizium-Brückenstahle), M. Kommerell. Bautechnik, vol. 4, no. 46, Oct. 22, 1926, pp. 686-688. Discusses experience of German Railway Co. with St 48, St 37 and Si steels, cost data, weights, strengths and loads, etc.

HIGH-SILICON. The Properties of Silicon-Rich Structural Steel (Die Eigenschaften des hochsilizierten Baustahls), E. H. Schulz and H. Buchholtz. Giesserei-Zeitung, vol. 23, no. 22, Nov. 15, 1926, pp. 615-622, 18 figs. Increasing yield point for rolled material by silicon addition of about 1 per cent; relation of strength properties to chemical composition; favorable influence of a higher silicon content on strength of steel castings; annealing at higher temperature than with pure carbon steel.

HIGH-TENSILE HEAT-TREATED. Use of High Tensile Heat-Treated Steel, D. B. Steinman and W. G. Grove. Boston Soc. Civ. Engrs.—Jl., vol. 13, no. 9, Nov. 1926, p. 379, 22 figs. Describes high-tensile heat-treated steel eyebars, being applied in Florianopolis bridge in State of Santa Catharina, South America; material used is carbon steel, but per cent of carbon is somewhat higher than carbon content in 30,000-lb. per sq. in. elastic-limit grade commonly used for structural purposes; steel is manufactured and rolled in larger eyebar sizes; bars are placed in heat-treating furnaces and subjected to temperatures necessary to produce elastic limits and ultimate strengths of desired amount; they are then quenched, reheat-treated and allowed to cool slowly.

TOOL STEEL

NON-DEFORMING. The Nature of Oil Hardening Non-Deforming Tool Steels, E. C. Bain and M. A. Grossmann. Am. Soc. Steel Treat.—Trans., vol. 10, no. 6, Dec. 1926, pp. 883-895 and (discussion) 896-897, 9 figs. Fundamental characteristics of oil-quenching type of tool steels; data were obtained from measurements of hardness, impact, strength, change of dimension, and determination of X-ray crystal structure; deductions are drawn as to preservation and subsequent destruction of austenite and this phenomenon is correlated with practical behavior of steel in its various uses.

TOOL STEEL

PROPERTIES. Tool Steel (Werkzeugstahl), R. Schäfer. Wärme, vol. 49, nos. 38 and 39, Sept. 17 and 24, 1926, pp. 669-675 and 689-692, 39 figs. History of development; structure formation of iron and steel in relation to carbon content; critical temperature; change of structure with rising or falling temperature; solid solution; hardening of steel; examples of hardened tools; hardening stresses; surface characteristics of steel products with regard to their stresses; notch hardness; high-speed tool steel.

WELDING

AIRCRAFT CONSTRUCTION. Tests in Connection with Gas and Metal Arc Welding as Applied to Aircraft Construction, H. B. Hird. Am. Soc. Naval Engrs.—Jl., vol. 38, no. 4, Nov. 1926, pp. 879-892, 7 figs. Results of tests conducted by Norfolk Navy Yard to determine thermal effect of gas and metal arc welding as indicated by tensile and bending tests on material; thermal effect on various gages of material; distribution of tension stress in material; effect of symmetrical deposits of weld metal on tubing; effect of annealing on gas and metal arc welded tubing; lightest gage metal which can be satisfactorily metal are welded, etc.

AIRCRAFT CONSTRUCTION. The Fusion-Joining of Metallic Materials Aircraft Construction, S. Daniels. Mech. Eng., vol. 48, no. 11a, Mid-Nov. 1926, pp. 1240-1246, 6 figs. Welding is primarily resorted to where joints form part of main airplane structure; describes technical methods of welding, and points out that oxyacetylene welding has successfully passed experimental stage, while electric-arc welding has not reached anything like same degree of development; gas welding, particularly in fuselage construction, has been applied not only to plain-carbon tubing, but to alloy-steel tubing, particularly chromium-molybdenum; specifications and methods for welding aluminum and aluminum alloys are given; brazing is mainly employed in connection with manufacture of fittings and is not relied upon for structural connections, while soldering is only used for such parts as gasoline lines and wrapped terminals.

FORD SHOPS. Advance in Ford Welding Practice. Am. Welding Soc.—Jl., vol. 5, no. 11, Nov. 1926, pp. 14-17, 2 figs. Welding is employed in four major forms; these, in order of their importance in Ford industries, are spot welding, butt welding, oxyacetylene welding and arc welding.

WELDING

RAILWAY PRACTICE. Autogenous and Electric Fusion Welding in Railway Upkeep (Die autogene und elektrische Schmelzschweissung in der Bahnunterhaltung), M. Perzl. Organ für die Fortschritte des Eisenbahnwesens, vol. 81, no. 19, Oct. 15, 1926, pp. 381-386, 5 figs. Discusses welding of broken tools and implements; castings, hardware, fittings; permanent way, tracks and general repair work; welding in place of riveting; metal cutting, etc.

WIRE

STEEL. The Manufacture of Iron and Steel Wire in Germany. Wire, vol. 1, nos. 1, 2, 3, 4 and 6, May, June, July, Aug. and Oct. 1926, pp. 58-59, 87-88 and 105; 118-119 and 136; 194-195 and 212, 15 figs. Translation of article by H. Altpeter published in Stahl u. Eisen, Apr. 16 and 23, 1925. See reference to original article in Eng. Index 1925, p. 785.

WIRE DRAWING

STEEL. Drawing Steel (Le tréfilage de l'acier), R. Galmard. Technique Moderne, vol. 18, no. 20, Oct. 15, 1926, pp. 614-622, 20 figs. Discusses fundamental phenomena, annealing, hammer hardening, drawing; drawing mills and their equipment, single and multiple drawing; automatic machinery, auxiliaries, etc.

WIRE ROPE

MANUFACTURE. Modern Wire Rope Manufacture in Germany, E. Trebesius. Wire, vol. 1, no. 8, Dec. 1926, pp. 274-275, 4 figs. Review of development; application of cast steel to rope manufacture. Translated from German.

NOTE. — The abbreviations used in indexing are as follows:
Academy (Acad.)
American (Am.)
Associated (Assoc.)
Association (Assn.)
Bulletin (Bul.)
Bureau (Bur.)
Canadian (Can.)
Chemical or Chemistry (Chem.)
Electrical or Electric (Elec.)
Electrician (Elecn.)
Engineer (Engr.[s])
Engineering (Eng.)
Gazette (Gaz.)
General (Gen.)
Geological (Geol.)
Mining (Min.)
Heating (Heat.)
Industrial (Indus.)
Institute (Inst.)
Institution (Instn.)
International (Int.)
Journal (Jl.)
London (Lond.)
Machinery (Machy.)
Machinist (Mach.)
Magazine (Mag.)
Marine (Mar.)
Materials (Matls.)
Mechanical (Mech.)
Metallurgical (Met.)
Municipal (Mun.)
National (Nat.)
New England (N. E.)
Proceedings (Proc.)
Record (Rec.)
Refrigerating (Refrig.)
Review (Rev.)
Railway (Ry.)
Scientific or Science (Sci.)
Society (Soc.)
State names (Ill., Minn., etc.)
Supplement (Supp.)
Transactions (Trans.)
United States (U. S.)
Ventilating (Vent.)
Western (West.)

News of the Chapters

BOSTON CHAPTER

THE Boston Chapter held their December inspection at the plant of the Hunt-Spiller Manufacturing Corporation, manufacturers of gun iron castings for frictional parts of locomotives and Diesel engines, and of brake drums for busses and trucks. Among the departments visited were the coal pulverizing plant; the iron foundry employing air furnaces burning pulverized coal and under constant temperature control with optical pyrometers; the core room and the finish machining departments. Opportunity was also given to visit the chemical and physical testing laboratories, including a laboratory devoted entirely to molding sand control and research.

Through the courtesy of J. R. Faden of the Edison Electric Illuminating Company, the facilities of the Edison Service Buildings in Roxbury were placed at the disposal of the chapter and seventy members and guests enjoyed an excellent turkey supper.

Following the secretary's report, R. F. Harrington, metallurgist of the Hunt-Spiller Manufacturing Corporation, under whose direction the afternoon trip was conducted, gave a brief history of his Company and a description of some of their products. Mr. Harrington said in part:—

"Among the great industries of New England, the manufacture of iron was the first to receive attention. Iron ore in considerable quantities was known to exist within the territory of the Massachusetts Bay Colony and as early as 1629 some steps appear to have been taken toward the manufacture of iron by the Court of Assistants in London, under whose patronage the colony was founded. During the next ten years deposits of bog ore were found in numerous ponds in Plymouth Colony and in 1652 iron manufacture was begun in Raynham. The "Old Colony" was known as the main seat of this industry in New England, out of which grew a concern which was later to become one of the principal manufacturers of cannon for the United States Government. This concern was known as the Algers Foundry and was founded in 1810, being later incorporated under the laws of Massachusetts in 1827 as the South Boston Iron Foundry.

"During the war of 1812 Cyrus Alger, who had specialized in ordnance work, produced large quantities of cannon balls for the Government. Mr. Alger had discovered a way to purify cast iron which gave it strength, nearly threefold that of ordinary iron castings, which proved to be of immense value to manufacturers of cannon and heavy artillery.

"The Company known as the South Boston Iron Foundry began the manufacture of heavy ordnance in the year 1828. Guns of large caliber were made at this time, the process consisting primarily of melting the original metal in a reverberatory furnace known as an "air furnace", allowing the metal to remain in fusion for an extended period of time, or casting and remelting the

same until such a time as the refining action gave the metal the desired physical properties, which were measured to a great extent by the increased density obtained. Here, under the direction of Mr. Alger in 1834, the first rifled cast iron gun ever made in the United States was produced.

"In 1842, the Columbiad, then by far the largest gun cast, was turned over to the Government by the South Boston Iron Works, and a report to the Ordnance Board of the War Department said that the cannon furnished by this company afforded the most favorable results and that the quality of the metal was unsurpassed. The gun was of 12 inch caliber and had a range of more than two miles.

"In a report to the Ordnance Department on April 2, 1844, Major Wade of the United States Army, shows some of Mr. Alger's work in making tests on heating the melted iron for different periods of time, which were carried out at the Algers Plant. Some of the results obtained were as follows:

First casting, made as soon as pig was melted	6506 pounds
Second casting, Iron in fusion 1 hour	7316 pounds
Third casting, Iron in fusion 2 hours	8256 pounds
Fourth casting, Iron in fusion 3 hours	8378 pounds

"The above shows a gradual and positive increase of strength as the iron is continued in fusion for longer periods of time. The reports also conclude that the high temperature makes for soundness and greater strength and go on to say that, although the transverse strength is that most generally measured, when the quality of different metals is compared, it is believed that a more accurate measure may be found in the tensile strength. Some of the figures in this connection are interesting:

	Density	Tenacity Pounds
Guns cast prior to 1841	7.148	23,636
Guns cast in 1851	7.289	37,774
10" Columbiad, cast 1851	7.304	45,970

"The first of the large cannon of 10,11 and 12-inch caliber, for the United States Government, were cast by order of the Government at the South Boston Iron Works under the direction of Mr. Alger, the latter selecting his own materials and using his own process. One of the guns, 11-inch caliber, carrying a solid shot of 170 pounds, or a shell of 135 pounds, was first fired 655 times with the former projectile and 1306 times with the latter, an enormous endurance of 1959 rounds before it failed, far exceeding any record of the Ordnance Department from this or any other country. This process was thenceforth used a great deal for gun castings, and hence the metallurgical term "gun castings" was created.

"While the South Boston Iron Works was said to be the principal builder of heavy ordnance, there were engaged in the casting of heavy guns between the years 1840 and 1850, two other companies, namely the Fort Pitt Foundry at Pittsburg and the West Point Foundry at Cold Springs, New York. It is

interesting to note that at about this time there was developed by Thomas Jefferson Rodman, a West Point graduate and an ordnance officer, a process of casting the guns hollow around a water cooled arbor, which was to revolutionize the casting of guns. Dr. Richard Moldenke states that between 1862 and 1877 there were no less than 272 Rodman guns, of which 103 were 15-inch in caliber and weighed 50,000 pounds each, produced at the South Boston Works.

"When the war broke out in 1861 it was necessary to make extensive additions to the plant and to undertake the construction of cannon of much larger bore than had been made. A new foundry was built and equipped with three air furnaces, each of 45-ton capacity, and a large number of 15-inch guns weighing 50,000 pounds per gun, were cast. Following the Civil War guns were produced weighting 80-tons as cast and 45-tons finished. One of the last contracts for the Government was for a gun which involved 120 tons of metal as cast, was 30 feet in length and weighed 54-tons when finished.

"The qualities which caused the adoption of this iron for the development of ordnance, induced its adoption by the railroads. Originally only a few railroads in New England used Hunt-Spiller gun iron in their frictional parts, but in recent years its advantages have become so generally accepted that railroads throughout the country have adopted it as part of their standard equipment. During the year 1917 Hunt-Spiller gun iron was specified and used in approximately eighty-five per cent of all locomotives purchased for domestic use.

"Recent years have also extended the use of the gun iron for Diesel engine work and more recently the material produced at the plant which you visited today has been used to manufacture the so-called gun iron brake drums for use on motor busses and trucks. Here again the characteristics which caused the adoption of the iron for heavy ordnance work and for the severest railroad service have been instrumental in producing a brake drum which has given unusual service."

The speaker of the evening was Francis B. Coyle, metallurgist of the United States Navy Yard at Brooklyn, New York, whose subject was the "Properties and Heat Treatment of Cast Iron for Diesel Engines". Mr. Coyle's paper dealt with the constitution, physical properties, artificial aging, annealing and heat treatment of high test iron. The paper was fully illustrated with a number of diagrams and tables showing the effect of composition and heat treatment on the physical properties. Considerable discussion followed, and in response to a number of requests from our own and other chapter members, an effort is being made to have the paper published in an early issue of TRANSACTIONS. *H. E. Handy.*

CHICAGO CHAPTER

The regular monthly meeting was held Thursday, October 14, at the City Club.

The newly elected officers made short talks. The speaker of the evening was R. P. DeVries, metallurgist, who gave an illustrated talk on "Character-

istics of Magnet Steels with Special Reference to Radio Requirements.'' The subject brought out a lively discussion.

The greatest gathering ever held by this chapter took place Thursday, November 4. The Chicago section of the American Institute of Mining and Metallurgical Engineers were invited to participate in the meeting.

Eddie and Fannie Kavanaugh (the Gaelic twins), radio stars from KYW, entertained during the dinner, keeping all present ''pepped up''.

The audience was agreeably surprised when the speaker and officers of the chapter were introduced over KYW. The announcer had evidently attended the convention last September and met some of the boys and was well posted on their pet hobbies. The speaker of the evening, Dr. W. M. Guertler, received a hearty reception. The subject, ''The Hardness of Metals'', was listened to with great interest.

An interesting discussion followed.

Thursday evening, December 9, the regular monthly meeting was held at the City Club.

During the dinner the members and guests were entertained by the McNeil Players in ''Banjo Oddities''.

Before introducing the speaker of the evening Chairman Baker introduced the chairman and secretary of the Chicago section of the American Chemical Society. These gentlemen outlined a course of evening classes on physics and chemistry to be given by University College of the University of Chicago.

The speaker of the evening was E. J. Janitzky, metallurgical engineer, Illinois Steel Company, who gave an illustrated talk on ''Temperature Distribution in Steel Bodies During Cooling.'' Mr. Janitzky is a big ''drawing card'' and brought out a full house. A spirited discussion followed the reading of the paper.

CINCINNATI CHAPTER

The Cincinnati Treaters enjoyed a most interesting feature at the December 9 meeting, when G. A. Richardson, director of publicity of The Bethlehem Steel Co., presented a five reel movie dealing with the manufacture of tool and alloy steel.

This moving picture showed the methods used in producing steel from the ore to the finished bar and showed as well some of the interesting methods used in the manufacture of certain specialties, such as car wheels and the like. Contrary to the usual run of mill and factory moving pictures, these films showed all of the manufacturing operations in great detail, so that each step in the process could be followed.

The melting is carried on in the electric furnaces which are charged with muck bar, analyzed billets cast from scrap, etc. At the proper time during the melting period slags are built up and suitable alloy additions are made. When the heat has been brought to the proper analyses and has been thoroughly deoxidized, the furnace is tilted and the metal is run into a ladle. From the ladle the metal is cast into ingots of the proper size for the bar to be rolled or forged. After the ingots have been inspected and chipped they are heated and cogged down. The bars are cropped at several stages in the rolling and

are given a final inspection for surface defects, fracture and pipe.

The manufacture of car wheels involves many interesting features. Bar stock is cut to the proper length for the wheel to be made, heated to forging temperature and pressure forged in a large hydraulic press of 12,000 tons capacity. This forging, after having a small hole blanked out of the center, is heated to the correct temperature and taken to the rolling machines which reduce the thickness of the flange and form the tread to the right dimensions. The hub is then machined, and in some cases, the tread, but for freight car service this is not necessary. After inspection and stamping the wheels are complete.

This meeting was attended by 200 members and guests and ended with a lively discussion.

R. J. Anderson, president of Robert J. Anderson Laboratories Company, will give a talk on casting, particularly in regard to the casting of aluminum alloys, at the next meeting to be held at the Engineers' Club, January 6, 1927.

E. M. Wise.

CLEVELAND CHAPTER

On Friday, December 17, 1926, the Cleveland Chapter of the American Society for Steel Treating had a very interesting meeting.

The first speaker was W. H. Eisenman, secretary of the National Society who spoke to us on some of his European trip experiences. They were interesting and so was Mr. Eisenman as usual. We can always listen to Bill.

The speaker of the evening was Swan Hillman of the National Lock Company, Rockford, Illinois, and his address was on "Cold Heading". Mr. Hillman divided his subject into three main parts, namely: Cold Heading, Thread Rolling and Standardization. The subjects included outlines with pictures of experiements Mr. Hillman has conducted. The experiments were very interesting and educational.

The outline of Mr. Hillman's talk started from the wire, through the cold heading operation with the many types of upsets, to thread rolling and the part the diameter of the wire plays to the size upset, into standardization of the product, eliminating specials where ever possible.

The speaker gave his paper in an excellent manner. After the address Mr. Hillman answered a number of questions. *A. E. Buelow.*

Members of the American Society for Steel Treating, and especially those of the Cleveland Chapter, regret the loss of one of their ardent workers and colleagues,—William F. Abel who died December 8, 1926, following a brief illness.

DETROIT CHAPTER

The October meeting of the American Society for Steel Treating was held October 18, 1926, on the 15th floor of the General Motors Building. The Society was extremely fortunate in having Coach Yost as their Coffee Talker. The Coach outlined some ideas on football and the general relation of athletics to good citizenship. At Michigan, the ideal situation is to compel all students to take some form of exercise and not to turn out a few highly trained experts.

Coach Yost then spoke of winning and losing games, stressing the point that he tries to teach his boys to fight to win, but to lose with a smile.

The technical speaker of the evening was T. S. Higbee, of the Victor Peninsular Company. His subject was, "Cold Heading." In presenting the topic, Mr. Higbee gave an outline of the cold heading industry. The first cold headed bolts were made from Swedish iron by Russell Burdsall Ward Bolt and Nut Manufacturing Company in 1850. The industry did not progress, however, until the advent of the Bessemer process for the manufacture of steel. Then also came the automatic screw machinery and the cap screw industry because an automatic screw machine product made from 1112 S. A. E. steel.

The waste of stock, particularly in long bolts, together with the upsetting of other types of bolts, encouraged the idea in cap screw manufacture. The greatest difficulty was that of the heads flying off. This can be remedied to a certain extent if the bolts are annealed. In standard practice, the bolts are heated to 1300 to 1500 degrees Fahr. and quenched in a soluble oil so as to produce the smooth black finish characteristic of most carriage and machine bolts of today. In the case of stove bolts, machine and wood screws, the mass of metal upset is relatively small and the applied stresses are low. Annealing is not so necessary.

With the advent of the automotive industry, the demands for cap screws became greatly increased. Successful cold headers of bolts began to consider the cap screw market and upset cap screws. That cold heading was a possible commercial production method was due to two causes:

1. Cap screws were a higher quality and a higher priced commodity than other upset products.

2. Cold upsetting methods saved enormous amounts of material over milling from the bar.

The first to start cold upsetting cap screws were the Material Screw and Manufacturing Company and the Ferry Cap and Set Screw Company of Cleveland. Their product was made of 1112 S. A. E. until the Ford Motor Company insisted on higher strength in the finished product. To this end, higher carbon steel was used, as .27 to .37. Due to the large amount of their product bought by the Ford Motor Company, the trade soon gained more experience with the material. Due to the general inexperience of the upsetting manufacturers with this steel, dies failed, machines were strained and many of the blocks split. This left a distaste for high carbon or alloy cap screws in the minds of most manufacturers.

The Victor Peninsular Co. then set out to produce a cap screw with the physical properties equal to or superior to the milled-from-bar product. As a result of metallurgical research and engineering development, facts were disclosed and converted into shop processes whereby 0.30 carbon to 0.37 carbon wire can be made economically into bolts which have a minimum of 70,000 lbs. in yield point and a Brinell hardness after heat treating of 241-196.

Mr. Higbee then outlined the developments which made possible the use of higher carbon wire. First he described the types of heading machines and the dies used. Briefly, the two flow header is most common and the dies used are solid or split. Both types have advantages, and both fail from the wear of

the metal passing through them. The typical failure is one in which the die allows bolts of too large outside diameter to be formed.

Wire is received 4 to 8 thousandths smaller than the finished product. This prevents sticking in the dies and allows a certain amount of work to be absorbed in the bolt proper. At each stage of the heading, Mr. Higbee presented examples of good and bad workmanship. The microscopic study of metal flow and deep etching to show cracks were shown for correct and incorrect tool handling.

Commenting on the type of steel used, Mr. Higbee said that the larger the grain size, the greater the amount of upsetting without rupture the steel could stand. In the case of fine grained steels (of higher carbon 0.30 up) it has been found that splitting is almost inevitable at normal heading speeds. Steels of from .30 to .80 carbon and 0.60-1.20 manganese may be handled with ease, but if the manganese gets above 1.60 per cent, the steel hardens so rapidly under cold work that the operation cannot be completed.

In closing, Mr. Higbee gave a formula for computing both areas:

$$EA = \frac{A + 9.5A'}{10.5}$$

EA equals effective area.

A equals major area.

A′ equals rivet area.

After the paper, discussion of the various points made by Mr. Higbee was given by members. Mr. Higbee was given a rising vote of thanks.

Lansing Extension Meeting of Detroit Chapter American Society for Steel Treating, Held Nov. 20.

This meeting held on November 20, 1926, marks in a most auspicious way what we hope will be the beginning of many more such meetings in Lansing. Sometime ago a decision was reached in a meeting of those interested at Lansing to organize as was done at Ann Arbor. Detroit now has the pleasure and honor of sponsoring two sub groups. The first one at Ann Arbor was the first student group organized preceeding that at Case by a few weeks in culmination and has been discussed for some time.

At Lansing the situation is related but somewhat different. There are quite a few industries where we have members, notably Reo and in addition the Michigan State College Engineering Department are keenly interested in the work of our society. In fact, their interest was such that for this first meeting they invited all out of town (Lansing or East Lansing) members as their guests at the football game in the afternoon. The game between Haskell Indians and State was interesting, but State was not able to stop the progress of the powerful Indians and lost 40 to 7. About thirty or forty, including some of our ladies, saw the game. After the game, as guests of the college, we inspected the laboratories of the engineering department. These included those of most interest to A. S. S. T. members, as forge shop, heat treating equipment for study of furnaces, pyrometers, etc., as well as the mechanics of steel treatment, foundry, with two small cupalos and an

electric furnace under construction, physical testing, metallographic and general metallurgical equipment, engine testing, etc.

The dinner served in the College Union on the Campus was a real success, about 120, including some ladies, being present. Of this number about 70 were from out of town. The Lansing committee introduced a Mr. Smith playing in the Capitol Theatre in Lansing who entertained us for about a half hour. At the places the Atlas Forge Company of Lansing arranged unique drop forged paper weights. The meeting then moving back to the R. E. Olds Engineering laboratory was officially welcomed, first by Mr. Hildorf of the Reo who is the chairman of the Lansing group. Mr. Atkinson, chairman of the Detroit Chapter, told of plans of Lansing also for further activities.

Dean Bissell of the Michigan State College Engineering school gave us the welcome of the college. He told of a meeting in his office earlier in the day at which plans for a most unusual course in metallurgical work were made. It has been recognized that the usual metallurgical courses aim more particularly at that type of such study dealing with the production of metals from their ores. We realize that here in Michigan and with developing industries a newer metallurgy of treatment of metals as such, is of growing importance. This new course at State is aimed to fit a man to make a real start in the line as we in A. S. S. T. know as metallurgical engineer. A very important move in connection with this new venture is the linking of it with, or rather the subdivision of it from the mechanical engineering department. This we think is a new idea, it being more common to link it with chemical engineering. It was the opinion of those at Dean Brissell's meeting that this plan was well founded. The course will earn the customary B. S. degree but certain graduate work, a degree of metallurgical engineer. As Dean Bissell pointed out it is extremely fitting that Michigan as the automotive center should make this move in a profession so vital in the automotive industry. While it is not expected that many will follow this this year, the plans are about consummated and will be under way next fall.

The speaker of the evening was Harold F. Wood of Wyman-Gordon Company, Harvey, Ill. His subject was, "Choice of Steels for Automotive Tool and Die Work." Mr. Wood is an old friend of ours in Detroit and received a hearty welcome. He analyzed the requirements of different main parts of an automobile and made up a series of his choices for these parts. He pointed out how need for better and quieter operation as well as longer life have necessitated more careful consideration of specifications in order to obtain the paramount "economical design." The classes given were:

1. Low stressed parts.
   a. Screw machine
   b. Miscellaneous forging for light sections as links, etc.
2. Medium stressed parts.
   a. Connecting rods
   b. Front axles
   c. Crank shafts

3. Highly stressed parts (Heat treated before machining)
   a. Steering knuckles
   b. Steering arm
   c. Axle shafts
4. Highly stressed parts (Heat treated after machining)
   a. Transmission gear
5. Low-stressed case-hardened parts.
   a. Camshafts
   b. Piston pins
6. Highly stressed case hardened.
   a. Ring gears
   b. Pinions
   c. Transmission gears (If case hardened)

For the most economical combination of properties, giving consideration of machining, heat treating and distortion, etc., he gave the various classes the following:

1. Elastic Limit .... 35,000 pounds per square inch minimum
   Elongation in 2" .... 16 per cent minimum
   Contraction .... 45 per cent minimum
2. Elastic Limit .... 70,000 pounds per square inch minimum
   Elongation in 2" .... 16 per cent minimum
   Contraction .... 50 per cent minimum
   Brinell Hardness 228-255
3. For alloy steels.
   Elastic Limit .... 110,000 pounds per square inch minimum
   Elongation .... 16 per cent minimum
   Contraction .... 50 per cent minimum
   Brinell Hardness 277-311
4. Hardness with best toughness possible
   Elastic Limit .... 235,000 pounds per square inch minimum
   Elongation .... 12 per cent minimum
   Contraction .... 35 per cent minimum
5. Uniform surface hardness
6. a. Uniform surface hardness
   b. Toughness and strength in core.
      Core after heat treatment to be
      Elastic Limit ... 70,000 pounds per square inch minimum
      Elongation ..... 16 per cent minimum
      Contraction .... 50 per cent minimum

In order to obtain these properties in steels with the necessary economy, consideration must be given to these factors:

1. Freedom from surface defects
2. Freedom from internal defects
   (a) Pipe
   (b) Segregation

(c) Laminations
(d) Snow flakes
(e) Internal ruptures
(f) Nonmetallic inclusions
(g) Hair line seams
(h) Ghost lines

3. Forgeability of Steel
   (a) Ease of flow
   (b) Relative liability of over treating
4. Design of part and stresses involved
5. Machinability
6. Response to Heat Treatment
7. Availability
8. Price

Mr. Wood then gave a thorough discussion of these factors. Pointing out for instance that a difference of 5 to 1 may exist in different steels as to forgeability. He cited examples of how lack of response to heat treatment may cause failures even with reasonable care given. He told of failures due to faulty machining and lack of fillets. In this connection he told of the life of motor busses of 250 to 300,000 miles and the few failures of crankshafts have all been due to lack of fillets. He pointed out how lack of cooperation between designing engineers and forge men often raises cost of parts unnecessarily. He then gave these steels as his choices for the various groups indicated above, using S. A. E. nomenclature:

1. (a) Free cutting Bessemer 1112
   For some work 1120
   (b) With normalizing treatment 1030
2. (a & b) Heat treated 1040
3. Various section encountered need variation in carbon from 35-45 choice 6140 giving consideration to all factors mentioned above.
4. Choice 3450, low hardening heat affecting such choice.
5. Choice 1020
6. Choice 3415, low hardening temperature reducing distortions.

For die work Mr. Wood pointed out that the logic used must be the same and his choice for drop forge dies intricate designs.

	per cent
Carbon	0.50-0.60
Manganese	0.50-0.80
Chromium	0.70-0.90
Nickel	2.75-3.25

He outlines a treatment that produces a surface 65-70 scleroscope.

For forgings in quantity and not intricate

	per cent
Carbon	0.50-0.60
Manganese	0.50-0.80
Chromium	0.55-0.75
Nickel	1.20-175 treated to 45-50 scleroscope

For small dies inserts are often used of these steels or some hot die steel. These retain their hardness hot as:

	per cent
Carbon	0.80-0.90
Manganese	0.50-0.60
Chromium	3.50-4.00

This is fair, but a better steel is:

	per cent
Carbon	0.40-0.50
Manganese	0.50-0.60
Chromium	3.0-4.00
Tungsten	15.0-18.0

For trimmer steel he prefers

	per cent
Carbon	1.00
Vanadium	0.15
Manganese	0.50 at 70-75 for Cold trimming or 65-70 for Hot trimming

Mr. Wood then concluded with a collection of lantern slides, largely of "pathological specimens" illustrative of the defects to avoid. *J. L. McCloud.*

Ann Arbor Group

At the meeting on Thursday evening, December 9, the Ann Arbor Branch of the Detroit Chapter was favored by the presence of the National Secretary, W. H. Eisenman, and J. M. Watson, metallurgist for the Hupp Motor Car Company of Detroit, Michigan. The former gave a short resume of the history of the Society and a short talk, especially appropriate for the large number of junior members present, students of the University of Michigan.

J. M. Watson gave a very interesting and instructive talk illustrated by moving pictures showing the purpose of heat treatment and the operation of automatically controlled continuous furnaces for the heat treatment of automobile parts as used in the Hupp Motor Car plant. He also showed pictures of the microstructure of the steel after each operation. He included in his talk and pictures the operations of normalizing, hardening, drawing, carburizing, and cyanide hardening.

Preceding the meeting, at which about 75 persons were present, eleven members of the Society had dinner at the Michigan Union. These members included the two speakers mentioned above, Prof. W. P. Wood, chairman of the Ann Arbor Branch; Robert Atkinson, Halcomb Street Company, chairman of the Detroit Chapter; W. G. Calkins, past chairman; F. P. Zimmerli, secretary-treasurer; H. G. Freeland, metallurgist for the Hoover Steel Ball Company, Ann Arbor; A. F. MacFarland, Cyclops Steel Company; Prof. H. L. Campbell of the University of Michigan; W. A. Anderson of Alfred O. Blaich Company, Detroit; and H. T. Morton, Jr., assistant metallurgist with the Hoover Steel Ball Company.

GOLDEN GATE CHAPTER

The Athens Athletic Club, Oakland, provided a very suitable meeting place for the Golden Gate Chapter of the American Society for Steel Treating, on November 10, 1926. A uniquely decorated and spacious banquet hall which was connected by sliding doors to the lecture room with used for the banquet. There were about 40 present at the lecture and banquet.

Chairman F. B. Drake presided over the meeting. As a roll call had not been resorted to for some months, each member was called upon to arise, announce himself and his business connections. The secretary's report was made and accepted.

Mr. Taylor presented the Year Book which is just off the press.

As this is the first Year Book that Golden Gate Chapter has produced, the members expressed themselves as being very proud of the work of the publicity committee in devising the booklet.

Mr. Wright, chairman of membership committee, made a few remarks regarding the coming membership drive and pointed out a few of the methods by which we hope to increase our membership.

Mr. Kottnauer announced that the details of the two courses—advanced and elementary—in the heat treatment of steel, were being worked out so that classes may start about January or February 1.

Chairman Drake brought to the attention of the members the new form of announcement of meetings which is being used. These announcements are much more elaborate than those formerly used and should be a means of creating greater interest in the meeting.

Several suggestions were made as to how these announcements might be improved.

Mr. Gearhart, who attended the Chicago Convention as representative of the Golden Gate Chapter, made a report of his trip. Among other things he stated that our chapter was well received and that he received every courtesy when it was known that he represented the Golden Gate. He was made chairman of the first technical session of the convention.

Mr. Thurston announced that the annual Smoker, which is slated for December 11, will be held at the States Restaurant in San Francisco. This is going to be a mighty classy affair, and Sam has promised us a big return for our $2.50 per capita.

The meeting of the executive committee was called for November 23, at the Athens Club.

The speaker for the evening was W. T. Brown, of Brown Brothers Welding Company, San Francisco. Mr. Brown is very conversant with his subject as he has successfully pioneered these two branches of welding in the San Francisco territory. His lecture was accompanied by many slides covering both types of welding principally in the shipbuilding trade. One of the impressive points brought out in his lecture was the fact that generally welded joints can be made stronger than the surrounding metal.

Mr. Brown is an electric welding enthusiast and believes there is a great future for this type of welding. In fact, he pointed out that there are many

cases where electric welding as developed today is the only feasible method.

C. E. Owens.

LOS ANGELES CHAPTER

The last regular meeting of the Los Angeles Chapter was held at the Los Angeles City Club Nov. 18, 1926. There were 54 members and visitors present, including two visiting members from the San Francisco Chapter, both claiming "We know how to do things down here in Southern California," and Mr. Howe, a charter member of the Chicago Chapter.

After a very splendid dinner and the transaction of regular club business, Prof. Howard Clapp, of the California Institute of Technology, Pasadena, California, was then introduced, and gave the last of a series of 12 lectures on the subject of "Heat Treatment and Practical Metallurgy." The subject, "Physical Properties of Steel under High Temperatures," was presented in a very clear and most instructive manner. Prof. Clapp has devoted a great deal of time along this line of researched work, having made many microphotographs which were shown on the screen during his lecture.

A rising vote of thanks was given Prof. Clapp for his untiring efforts in arranging this lecture course for the Los Angeles Chapter and all wish him success along this line of endeavor at the California Institute of Technology.

E. C. Black.

MILWAUKEE CHAPTER

Milwaukee Chapter's first social event was held on November 16, 1926, at the Republican Hotel.

Among the events of the evening was an entertainment which was enjoyed by all. Smokes and refreshments were served during the entertainment, which was followed by a banquet.

The evening activities were enjoyed by about 180.

The program and arrangements were under the auspices of J. J. Dierbeck, chairman of entertainment, to whom we wish to extend our sincere appreciation for a most enjoyable evening.

Milwaukee Chapter held their regular monthly meeting November 23, 1926, at the Blatz Hotel. The 6:30 dinner was well attended as well as the lecture at 8:00 p. m.

The speaker of the evening was E. W. Stuart of the Wm. D. Gibson Company, Chicago.

The subject of springs was discussed very thoroughly, their design, manufacture, heat-treatment and operating conditions.

This was a very interesting meeting as was evidenced by the number of questions and amount of discussion. *M. E. Greenhow.*

MONTREAL GROUP

The members of the executive committee of the Montreal group of the American Society for Steel Treating have been so busy during the fall getting in new members, and getting the course in metallography and steel treating under way, that there has been little time for writing reports for TRANSACTIONS.

However, now, the success of the Montreal group is assured. Since the start of the group in Montreal last April more than 100 members have signed up, and while there are some defaulters among these who are not yet eligible for membership, yet the Montreal group is head of class three, and what is more, the members have the determination to stay head of class three or whatever classification group into which they are placed.

One of the best means of getting new members has been the course that was started in cooperation with McGill University. The fees for this course were set as $5 for members and $10 for non-members, and it was responsible for getting many of the new members. More than fifty registered for the course, which was based to a certain extent on a similar course being conducted at Temple University in Philadelphia, and all fall there has been an attendance at the weekly lectures of more than forty. Instruction has been provided by members of the lecture staff of the university, and practical men prominent in the steel industry in Montreal. The instructors include Dr. Alfred Stansfield, chairman of the Montreal Group, C. F. Pascoe, vice-chairman, Robert Job, Gordon Sproule, and W. M. Townsend, members of the executive committee, and Messrs. Roast and Collitt, members of the society.

All of the lectures have been more or less of an elementary nature, in order that those members of the class who are beginners might not be handicapped. Next year, if this year's class continues to be the success that it has been all fall, the instruction will probably be carried forward into more advanced studies. But, it is impossible to progress very far with the elementary work in 25 lectures.

Three lectures have been heard by the Montreal Group during the fall; T. H. Nelson, speaking on a comparison between the methods of manufacture of high grade steels in England and the United States; Mr. Norris of Vanadium Steel Company, on vanadium steel, and Sam Tour of the Doehler Die Casting Company, Batavia, New York, on salt baths.

A good program has been arranged for the 1927 season, and several speakers have already been obtained. The first meeting will be on January 10.

At the first meeting in the fall the executive, appointed temporarily, was authorized to act until the first election of officers. This executive consists of chairman, Dr. A. Stansfield, McGill University; vice-chairman, C. F. Pascoe, Canadian Steel Foundries; secretary-treasurer, F. H. Williams, Canadian National Railways; executive committee: Robert Job, Milton Hersey Company Limited; R. J. Noakes, Canadian Pneumatic Tool Company; Gordon Sproule, McGill University; W. J. Hall, Manufacturers' agent; W. M. Townsend, Montreal Locomotive Works Ltd.; H. S. Weldon, Canadian Inspection and Testing Company Ltd.; W. J. Pead, Montreal Heat, Light and Power Company, and D. G. Mac Innes, Canadian Machinery and Manufacturing News.

NEW HAVEN CHAPTER

The regular monthly meeting of the New Haven Chapter was held on Thursday, December 9.

At 6:30 p. m. 21 members and friends sat down to a roast turkey dinner at the Hotel Bishop.

Shortly after 8 p. m. the chairman, C. J. Sauer, opened the meeting and a short business session was held. Following this, the speaker of the evening, Charles McKnight, Jr., of the development and research department of the International Nickel Company, gave a very interesting and instructive talk on "Some New Steel Developments." This talk was well illustrated with lantern slides. The topic itself was along new lines and so different from most talks on steel, that it was well on to eleven o'clock before the questions were all answered.

The attendance prize donated by R. G. Hall was won by T. G. Besom. More power to you, Tom. Don't forget to be on hand for the next meeting.

Due to the snowy condition of the roads and the cold weather, our attendance dropped down to 45. Congratulations to the ones who braved the elements. You were well repaid by a mighty interesting talk. *W. G. Aurand.*

NORTHWEST CHAPTER

The Northwest Chapter was fortunate to procure speakers for two meetings for December. At the first meeting held Dec. 7, Mr. Harcke of the Air Reduction Company gave a talk on the properties of liquid oxygen. Even though the oxygen contained in cylinders is a common article in most shops at the present time, its properties in the liquid form are not very well known to most of us.

Mr. Harcke showed its effect on flowers, rubber, and other articles, which demonstrated very well just how this liquid behaves. Its most useful property, that of supporting combustion, was shown by immersing a glowing splint into the vapor above the liquid which caused the splint to burst into a bright flame. The talk was very interesting as well as entertaining, with everybody anxious to see what Mr. Harcke would do next.

After the lecture, a moving picture film was shown which described and illustrated the machines used in the manufacture of liquid oxygen. Another film showed the use of oxygen in oxyacetylene welding and cutting of metal. The pictures of the welding operations were especially interesting as the making of a weld was so well illustrated.

After the lecture there was a good discussion on difficulties met with in making welds of various types and using different kinds of material.

The second lecture was given December 15, by A. W. Lorenz, metallurgist of the Bucyrus Company, South Milwaukee. Mr. Lorenz gave a talk on steel castings and discussed the furnaces used, giving the advantages and disadvantages of the different types. He also discussed the methods used in the heat treatment of castings and showed how each would be best suited for various types of steel and properties that are desired.

After the lecture there was a good discussion on the heat treatment of steel castings as well as on the best practice for casting steel. Mr. Lorenz presented this difficult subject in a very clear and concise way so that everybody present obtained a great deal of information which can be applied to their own problems. We feel especially fortunate in having had Mr. Lorenz present this paper to us. *L. J. Weber.*

PITTSBURGH CHAPTER

The December meeting of the Pittsburgh Chapter was held on the evening of the 2nd.

An unusually large number of members attended the supper which was served at 6:30 p. m. in the Bureau of Mines restaurant preceding the meeting.

At 8 o'clock, the meeting was called to order in the auditorium of the Bureau of Mines Building. Owing to the absence from the city and illness of the chairman and vice-chairman, former Chairman O. B. McMillen was called upon to preside at this meeting.

After a short business session, the chairman introduced the speaker of the evening, O. L. Pringle, superintendent of the metallurgical and inspection departments of the Pittsburgh Crucible Steel Company, Midland, Pa., whose subject was, "A Review of Some Phases of Modern Steel Manufacture."

A great number of specifications for forging billets, especially for locomotive forgings require that blooms shall be rolled from an ingot which will give a reduction of from four to one from ingot to billet. In the early days this requirement might not have caused any detrimental effect, but since the size of these billets are becoming larger and larger and the restriction of four to one reduction is required, we find that the ingots are becoming increasingly larger as time goes on.

To determine by a detailed investigation the effects of various amounts of reduction from ingot to bloom on the quantity of the steel as shown by its static and dynamic properties, an investigation was made of the static and dynamic physical properties by pouring the steel from one heat into four different size molds, namely, 18 x 18, 20 x 20, 26 x 26, and 32 x 32 and roll these ingots into 14 x 14 with an ingot to bloom yield of as near 70 per cent as possible in each case. Both top and bottom ends were analyzed center and midway for carbon, and bottom and top etch tests were taken from each bloom. The amount of reduction was as follows:

Ingot Size	Reduction of Ingot From 14 x 14
18 x 18	1.65-1.00
20 x 20	2.04-1.00
26 x 26	3.44-1.00
32 x 32	5.22-1.00

The etch tests showed little difference and, if anything, favored the blooms with the least reduction and the physical properties, both static and dynamic, favored the 2.04 to 1.00 and the 3.44 to 1.00 reductions. A discussion followed as to the explanation of this.

The speaker then called attention to the report of sub-committee No. 5 of the Iron and Steel Institute on "The Heterogeneity of Steel Ingots." It was brought out that these ingots were made on the continent and ranged in size from 1500 pounds to 172 tons in weight.

It was recommended that the Pittsburgh Chapter consider the help that they might give the steel industry, not only in Pittsburgh, but United States by making such an investigation and publishing such results with the idea of

getting to the trade not only the difficulties, but in some cases the possibility of meeting certain restrictions of specifications which had nothing more than an arbitrary origin.

Reference was also made to the findings of J. H. S. Dickenson of the Iron and Steel Institute of "The Distribution of Silicates in Steel Ingots" with the comments of such men as Mr. H. Brearley and several others of international Ferrous-Metallurgy fame.

It was not recommended in any way that there be any let-up or easing off of the requirements of specifications that had good foundations for their existence, and it was only the arbitrary and obsolete requirements of specifications that were asked to be investigated and modified accordingly.

H. A. Neeb, Jr.

ST. LOUIS CHAPTER

The sixty-second monthly meeting of the St. Louis Chapter, American Society for Steel Treating was held Friday evening, December 17, at the American Annex Hotel, with 41 members and guests present.

After the usual dinner, the meeting was called to order by the chairman, C. B. Swander, who announced that we were shy a vice-chairman, on account of J. J. Bowden of Laclede Steel Company taking up new duties in the East. As the St. Louis Chapter was in need of a "Vice", Guy White nominated W. D. Thompson of Laclede Gas Company, who was elected unamimously to be St. Louis Chapter's only "Vice."

The secretary then reported four new members—J. J. Larkin, president, and Jim Kilger, superintendent of Larkin Packer Company, A. W. Grosvenn, Jr., transferred from Cleveland, Ohio, and K. G. Lund from Pittsburgh.

The speaker of the evening, G. E. Harcke, industrial engineer and director of the Airco-Davis Bournonville Welding Institute, Jersey City, N. J., assisted by his associate, J. F. Callahan, through the courtesy of the Air Reduction Sales Corporation, 342 Madison Ave., New York, having been produced by this company in co-operation with the United States Bureau of Mines, the educational film "Oxygen, the Wonder Worker" was presented, showing its use in the fabrication, salvaging and wrecking in the industries, and a demonstration of the properties of liquid oxygen proved most interesting. Rubber balls, tubing, hot-dogs, and fruit immersed a few seconds, showed some spectacular results. Just imagine 300 degrees below zero bottled up and under control in a room filled with men, at 70 above, and you will know why the writer thinks every man who failed to be there missed a treat. The meeting was both interesting and instructive, and was closed with a rising vote of thanks to the speaker and his associates.

C. G. Werscheid.

SYRACUSE CHAPTER

A. H. d'Arcambal, consulting metallurgist of the Pratt and Whitney Company, was the speaker at the regular monthly meeting of the Syracuse Chapter held on December 14. The subject of the talk was "Metal Cutting Tools".

The speaker first reviewed the changes that have taken place in the last few years in the metal cutting tool industry. He recounted that seven years ago practically no tool steels were made in the electric furnace. Three years

ago about fifty per cent of the tool steels were made in the electric furnace and today from ninety to ninety-five per cent is manufactured in the electric furnace. He said that it is now believed that electric furnace steel is better than crucible steel. The high speed steel in use today is mainly of the eighteen per cent tungsten, one and a quarter per cent vanadium type with carbon between 0.65 and 0.75 per cent. The use of cobalt high speed steel, with cobalt up to five per cent is coming more into use for turning and boring tools. It seems to be difficult to harden this steel without producing a soft skin, and for this reason it is not advisable to use this steel for any tools except those which are ground all over. The special steels like molybdenum high-speed and the so-called semi-high speed have fallen by the wayside. A steel which has won a popular place in the field of blanking dies is the high carbon high chromium type. For low speed cutting, the vanadium-treated carbon steels seem to be best. In concluding the discussion of the steels, the speaker pointed out that rejection of steel at the customers' plants has fallen off to a very low percentage due to improved methods and more thorough inspection by the steel manufacturer. He further advised that large users should buy steel under specifications such as analysis, hardness and acid etch test, thus placing the responsibility on the buyer; but small shops, not properly equipped for testing, can do no better than buy steel by brands.

In regard to changes in hardening equipment, the speaker stated that one of the greatest boons to the hardener is the automatically controlled electrically heated lead and salt bath furnace. Further, if the glow-bar high speed furnace lives up to its promise, it is quite likely that the hardening rooms of Pratt and Whitney will in a short time be completely electrically equipped, thus assuring clean and accurate work. The Rockwell dilatometer method of hardening is another recent development.

The only important change in testing equipment has been the rapid growth in popularity of the Rockwell hardness tester.

In tool design, the most important change has been the development of the ground thread high speed tap. These taps give eight to ten times the service of a carbon steel tap.

The speaker then showed pictures of the various departments of the Pratt and Whitney works, at the same time extending an invitation to all to come and visit the plant.

In concluding his talk, the speaker illustrated by means of many specimens he had with him, the effects of good and bad heat treatment, as well as good and bad acid-etched discs.

The discussion that followed was quite animated and everyone in the large audience felt that he had spent a profitable evening. *S. P. Peskowitz.*

TORONTO CHAPTER

An illustrated talk by M. A. Grossmann, of the Central Alloy Steel Corporation, Massillon, O., on "Some of the Precautions Taken in Making Fine Steels," was the feature of the November 26 meeting of the Toronto Chapter of the American Society for Steel Treating.

About fifty members were present in the Consumers' Gas Company hall,

Adelaide Street, Toronto, when J. W. McBean, chairman of the chapter, called the meeting to order. W. J. Blair, of the executive committee, announced prior to Mr. Grossmann's talk, that half a dozen members had been secured since the October meeting, and that as many more would be secured before the December meeting. The finances of the chapter were also in much better condition, Mr. Blair said, largely by reason of a booklet evolved by the executive committee, from which the advertising revenue had been more than satisfactory.

Urging all interested in the heat treatment and manufacture of steel to join, Mr. Blair declared the publications furnished members by the society were alone worth the fee, apart from the meetings and lectures. Another indication of the importance of steel treaters and the manner in which members were being served was the appearance in Canadian Machinery and Manufacturing News, the official organ of the chapter, each week of a page edited by members of the society and devoted to heat treating topics. Mr. Blair announced that arrangements were being made to publish a photograph and biography of every member of the chapter, as one means of "getting acquainted".

In covering his subject, Mr. Grossmann followed fine steel through the mill from the scrap pile to the stock pile, emphasizing the care given its manufacture. Slides showing each operation were of considerable benefit to members in following the discussion. The speaker pointed out that fine steels include tool steels, made with great care in composition and structure and consisting of several groups, i. e., carbon, high-speed, non-shrinking, etc.; so-called alloy steels, used largely in the automotive and locomotive fields, comparatively low in carbon; and the so-called stainless steels, first manufactured by Krupp, although Brearley was first to realize their importance.

High speed steels, said Mr. Grossmann, are undoubtedly the most sensitive of the steel family and eight-inch and larger ingots require very careful handling, as otherwise they simply fall to pieces in the "breaking-up" operation under the hammer.

The final operations of chipping, grinding, annealing or cold drawing of the billet were discussed by Mr. Grossmann who showed that great care had to be taken to the very last operation. In grinding surface imperfections from the billets, for instance, the wheel is run crossways of the billet to avoid smearing over any longitudinal cracks.

In connection with the annealing, Mr. Grossmann declared a fallacy was gaining credence, that decarburization was caused by annealing. This, he declared, was not so. The annealing operation merely defined the line of demarcation, as the same effect was secured when the billet was annealed in a vacuum, when decarburization certainly would not occur.

At the conclusion of his talk, Mr. Grossmann answered many questions relating to individual problems, propounded by J. L. Hynes, of the Crucible Steel Company; A. G. Davis, of the Consumers' Gas Company; W. J. Blair, of Canada Cycle and Motor Company; E. Burnthall, of the Corman Engineering Company, and J. W. McBean, of the Central Technical School.

Campbell Bradshaw.

TRI-CITY CHAPTER

The third regular meeting of the Tri-City Chapter of the American Society for Steel Treating was held at the LeClair Hotel, Moline, Illinois, on November 17, 1926, at 6:45.

Forty-five members and friends were present to enjoy the dinner and to hear N. L. Deuble of the Central Alloy Steel Corporation of Massillon, Ohio, talk on "Heat Treatment of Steel Parts for Motor Cars".

Mr. Deuble's talk was enlightening and included recommendations for the steel to be used in the construction of automobiles and tractors, together with the heat treatment of them. Local tractor and automobile manufacturers were keenly appreciative for the opportunity to hear a talk of this kind.

In December a joint meeting of the Tri-City Chapter of the American Society for Steel Treating and the Quad City Foundrymen's Association was held.

Approximately eighty men attended the joint December meeting of the Steel Treaters Society and the Foundrymen's Association.

The dinner, which preceded the talk of the evening, was featured by a Hawaiian musical sketch put on by Messrs. Willers and Pasch, both of Davenport.

Mr. Lorenz, metallurgist for the Bucyrus Company of Milwaukee, manufacturers of heavy steam shovels and locomotive cranes, discussed the manufacture of steel castings and their proper heat treatment. He stated that at the plant with which he is connected he found that steel castings can be made cheaper and of a better quality if they are melted in an electric furnace than if melted in the basic open hearth. The question was raised why electric furnaces could not be used to equal advantage for melting gray iron. An informal discussion followed.

WASHINGTON-BALTIMORE CHAPTER

The Washington-Baltimore Chapter held its November meeting on the 19 in the Engineers Club, 6 West Fayette St., Baltimore, Md. Dr. F. C. Langenberg, Howe Medalist for 1926, addressed the chapter on the subject "Practical Applications of the Impact Test". A brief outline of this talk and of the discussion follows:

It will be well to mention at the start that the application is in the testing of cold-worked cylinders. If a sample hollow cylinder is subjected to an interior pressure, the outer surface of such a cylinder is under a low stress while the inner surface is under a high stress. It may be shown that in the case of a cylinder in which the wall thickness is equal to the interior diameter, the greatest pressure which can be confined in such a cylinder without stressing the inner surface beyond its elastic limits is only 63 per cent of the elastic limit of the steel from which the cylinder is made. The stress at the outer surface of this cylinder is only 3/19 of the stress at the inner surface.

If the problem is presented of designing a cylinder which will function elastically under a given pressure, two conditions can be carried; namely, the elastic limit of the material to be employed, and the wall thickness, assuming that the interior diameter must be some fixed dimension. There are certain limitations on the use of material having a high elastic limit, for some ductility

must be present. Likewise, increasing the thickness of the cylinder wall beyond a certain amount does not materially increase the elastic strength of the cylinder. It is obvious that if the metal in the bore could be compressed to its elastic limit in compression, the elastic range of the cylinder would be doubled. If the bore is stressed beyond the elastic limit and the applied stress then is removed the metal at the bore will be found to be in a state of compression, whereas the metal at thè outer surface of the cylinder will be in a state of tension. In analyzing the conditions existing in a cylinder which has been subjected to cold working, it is obvious that in addition to the compression existing at the bore a source of additional elastic strength is present. If the bore of such a cylinder has been enlarged, the outer wall will also have been enlarged, but by a lesser amount depending upon the thickness of the cylinder wall. This enlargement is equivalent to a tangential stretching of the metal, and the original elastic limit is elevated to some new figure, depending upon the amount of stretch in the various elements of the cylinder wall. It is evident that the maximum increase of the elastic limit will occur at the bore of the cylinder. Therefore, in determining the strengthening effect imparted by the cold working operation, it is necessary to take into account, not only the compression of the metal at the bore, but the elevation of the elastic limit as well. Some additional strengthening effect is produced by heating at 250 degrees Cent. subsequent to cold-working. For instance, the increment of increase in elastic strength produced by an additional 0.50 per cent enlargement of a cylinder having had a previous 3 per cent enlargement followed by the 250 degrees Cent. annealing operation, is much greater than the increment would be if the cylinder were enlarged from 3 per cent to 3.50 per cent without an intervening anneal. In general, the increase is elastic strength, produced by the low anneal, is less at the higher bore enlargements.

In the actual manufacture of guns by this cold-working process the following scheme is used:

A container is erected in a vertical position and the gun lowered into place. A mandrel is placed inside of the gun with a small clearance around it. Packings are provided at each end of the gun and water pressure is applied through a pump and then an intensifier to increase the unit pressure. The interior contour of the container is so machined that each section of the gun will receive the proper enlargement, and after this enlargement has been obtained further expansion is prevented by the walls of the container.[1]

When centrifugally cast guns are prepared, metal is poured into a rotating, refractory-lined mold, the largest one used in the Watertown Arsenal being 18 inches outside diameter and 15 feet long. The cast cylinder is then heat treated, subjected to the cold-working operation described above and annealed at 250 degrees Cent. In these centrifugally cast cylinders carbon and other elements such as chromium, sulphur and phosphorus segregate toward the bore. This phenomenon is illustrated by the carbon analysis of a section five inches thick, from the bore to the outer surface, the carbon present in the region near the bore being about 0.50 per cent and that present near the outer surface being only 0.15 per cent. The corresponding Brinell hardness was 190 at the

[1]Effect of Cold-working on the Strength of Hollow Cylinders by F. C. Langenberg. TRANSACTIONS of American Society for Steel Treating, 1925, Vol. VIII., pages 447-470.

bore and 130 at the outer surface. There is no gradual decrease in carbon content from the bore to the outside, a more rapid rate of change being observed near the bore. Manganese does not seem to segregate when present in small quantities, but it does segregate when larger amounts (1 to 3 per cent) are present. It is important to note that segregation in these castings is on a much sharper gradient than in masses of equal weight or area, cooled at the same rate but without the influence of outside forces other than gravity.

This segregation in pressure cylinders is not entirely disadvantageous particularly after heat treatment and subsequent cold work. It leaves the inner metal of high elastic limit, although of low ductility; it is this metal that must take the highest loads but tensile failure here can never prove serious. This is brought about by the outer metal being of low elastic limit and lightly stressed, but highly ductile and very resistant to impact. When a cylinder of this type fails, it splits but does not fragment and thus life and property damage are at a minimum.

Returning to the question of impact testing, Dr. Langenberg remarked that previous investigations of ordnance material that had seen service (some of which had failed) made possible the establishment of minimum Charpy impact values for these materials. Continuing the study of impact properties in the case of the cold-worked cylinders brought out the facts that with absorbed energy in this test below 7, failure would occur with fragmentation; between 7 and 12 the nature of failure was variable and over 12 failure was in every case by longitudinal splitting without fragmentation.

In attempting a correlation of static and impact properties, various materials were examined by static tensile tests of standard 0.505 inch bars and impact tests of un-notched bars of similar form and notched bars in which the diameter at the base of the notch was also 0.505 inch. Certain interesting relationships were developed between the strength properties in static tension tests, the energy absorbed in such tests and the energy absorbed in the impact tests but in order to develop these features, energy absorption in static testing had to be computed to the instantaneous reduced area while under load. The elongation in the immediate vicinity of the "neck" of the tensile bar affords an index of impact strength. These experiments have further indicated that the static tensile tests may be replaced by the less expensive impact test in the examination of the serviceability of these cold-worked cylinders.

A. I. Krynitsky.

WORCESTER CHAPTER

The regular meeting of the Worcester Chapter, American Society for Steel Treating, was held on Tuesday, October 26, at the Worcester Polytechnic Institute. The meeting was preceded by the usual supper—there being present a total of fifty members and guests.

Vice-Chairman, H. Klauke, presided in the absence of our chairman, Earle Clark. Sorry Earle could not attend as this meeting was one of our most successful meetings. We had over one hundred present at the lecture which followed the supper.

The speaker for the evening, G. A. Richardson, of the Bethlehem Steel Company, gave one of the most interesting talks ever presented before the

chapter. Believe me, Mr. Richardson is some "Iron Man". He drove some 280 miles over the road just before giving this talk on "Manufacture of High Grade Steel".

Several films were projected in connection with this subject. The first film and talk covered the general manufacture on a large scale. The large tonnage methods were clearly outlined. The second talk covered high grade steel manufacture taking in the special methods of manufacture that are independent of the manufacture of the regular tonnage steels.

Lastly one of the highly specialized methods of manufacture was considered, showing a film on manufacture of forged car wheels. This proved very interesting and spectacular.

After completing his talk Mr. Richardson was given a rising vote of thanks. *C. G. Johnson.*

The fourth meeting of the Worcester Chapter was held Thursday evening, December 2, at Baratti & Ble's Restaurant. This was a joint meeting with the American Society for Mechanical Engineers. Nearly sixty were present at the luncheon served at 6:30 o'clock p. m.

After a leisurely luncheon the meeting was called to order by Chairman Clark. The regular business announcements were made after which H. A. L. Woodcock, of the Morse Twist Drill and Machine Company, speaker for the evening, was introduced.

Mr. Woodcock gave an illustrated lecture on the development of New Bedford, Massachusetts, including pictures of the Morse Twist Drill Plant with a talk on tools. The whaling industry was responsible for the founding of New Bedford, and with the dropping off of this industry it was necessary for New Bedford to find other lines of industrial work—one of them being machine tools. Mr. Woodcock's description of the whaling industry was very good and we all enjoyed it. The talk on the development of the Morse Twist Drill Company was very interesting. This factory was one of the first to manufacture machine tools including the twist drill. A good many problems of the manufacturer of machine tools were described. *C. G. Johnson.*

The Worcester Chapter is to be congratulated for its efforts in establishing a course in metallurgy which is now well under way. The course started on October 7. Through the cooperation of the Y. M. C. A. Engineering School with the Worcester Chapter of the American Society for Steel Treating this course in metallurgy has been made possible.

The course consists of 32 lectures by V. E. Hillman, metallurgist of Crompton & Knowles Loom Works, and covers subjects indicated in the following outline:

Iron Ores
Blast furnace
Acid Open-hearth furnace
Basic Open-hearth furnace
Bessemer steel
Electric steel
Fluxes
Ferro-alloys
Various grades of steel
The elements: Sulphur, Phosphorus, Manganese, Carbon, Chromium, Nickel, Tungsten, Vanadium
Hardening—drawing—annealing—carburizing
Recalescence and decalescence points
Microphotographs and their practical application

Complete discussion of:
- Pearlite
- Martensite
- Troostite
- Sorbite
- Ferrite

Wrought Iron:
- Slag Fibers
- Transverse section
- Longitudinal section
- Segregation

Cast Iron and Malleable Iron:
- Cementite
- Graphitic carbon

- Brinell machine
- Scleroscope
- Tensile strength testing machine
- Metallographic bench

- Heat treating furnaces
- Different quenching mediums
- Various drawing baths

The Worcester Chapter of the American Society for Steel Treating recommends and endorses this course and urges anyone interested to call Mr. Lotz at the Y. M. C. A.

This is the first time such a course has been available in Worcester to the general public.

DISCUSSION—TENSILE PROPERTIES OF STAINLESS IRON AND OTHER ALLOYS AT ELEVATED TEMPERATURES

(Continued from Page 100)

represents the condition of all the others, I will say that we have found it necessary to use extreme care in selection of test specimens. Bars are checked by Brinell test after quenching and after tempering before the first selection of uniform material is made. Seven Brinell tests are then made on each bar to determine, if possible, the presence of any hard or soft spots. All of the bars in the lot are then machined to final form and tested magnetically. The Brinell and magnetic tests usually agree in the arrangement of specimens in the order of their strength. A short-time tensile test at normal temperature is then made on at least two of the hardest and two of the softest bars in the lot. The variation in properties of these bars represents the maximum variation to be expected in the lot of material. Test specimens chosen for long-time tests are the ones showing the greatest uniformity in these preliminary tests.

I wish to thank Mr. French especially for the supplementary information he has given in connection with long-time tensile tests at high temperatures. Such tests afford a means of selecting safe working stresses at elevated temperatures. In general this selection must be based on allowable deformation within the expected life of the material. In steam-turbine practice, a long life is expected and the allowable deformation is extremely small. In checking working stresses for this application, we feel justified in going to the utmost refinement in strain measurement. Unless this is done, tests must be conducted over long periods of time to determine whether or not "creep" is taking place. We are at the same time making short-time tests and trying to determine some method of predicting the results now obtained from the long-time tensile test.

Items of Interest

D. W. BRUNTON, consulting engineer, Denver, has been named recipient of the William Lawrence Saunders medal and Zay Jeffries, metallurgical engineer, Cleveland, recipient of the James Douglas medal, according to an announcement of the American Institute of Mining and Metallurgical Engineers, under whose direction the awards are made. Presentation ceremonies will take place at the annual meeting of the institute in New York next February.

The Saunders medal, established in honor of one of the institute's former presidents and being awarded for the first time, goes to Mr. Brunton for development and exposition of the principles and practice of ore sampling; for systematic daily mapping of mine geology; for the Brunton mining compass; and for engineering achievements in connection with modern high-speed tunnel driving.

Dr. Jeffries is the fifth recipient of the Douglas medal and received recognition for distinguished achievement in nonferrous metallurgy. His

DR. ZAY JEFFRIES

chief achievements are developments of a method for measuring grain size of metals; explanations of the phenomena connected with grain growth in and deformation of metals and the effect on their physical properties; development of crystal analyses of metals by X-Ray; theory of the causes of hardening of metals and alloys, especially steel, and the red hardness of high-speed steel. Aluminum pistons, heat-treated aluminum castings and new types of high-strength wrought aluminum alloys are some important developments attributed to Dr. Jeffries.

E. Leitz, Inc., 60 East 10th Street, New York City, has available Pamphlet Proj. H. 2180, entitled "Profile Drawing and Projecting Apparatus"

(Continued on Page 34 Adv. Sec.)

for testing the profiles of industrial products of all kinds. This new and improved contour projector is now on the market. This instrument is not expensive and is within easy means of manufacturing plants. The apparatus is of handy design and serves for the exact control of technical profiles such as small and even minute, components of clockwork movements of watches, fine instruments, gears, tools, etc. The apparatus is extremely easy to manage and projects upon a surface silhouettes of objects and furnishes a precise means of checking the slightest departure from the required standard.

Fred A. Geier, member A. S. S. T., president, Cincinnati Milling Machine Co., Cincinnati, has been appointed a member of the board of directors of the Cincinnati branch of the Federal Reserve Bank.

Ambrose Swasey, member A. S. S. T., president of Warner & Swasey Co., Cleveland, builder of turret lathes and precision equipment, and renowned as the designer and constructor of large telescopes, celebrated his eightieth birthday, Dec. 18, at his home in that city. Among the many telegrams and messages of congratulations he received was one from his partner, Worcester Reed Warner, who was 80 years old last May.

Harry G. Stoddard, member A. S. S. T., treasurer of the Wyman-Gordon Co., Worcester, Mass., manufacturer of automobile crankshafts and castings, has been named to the directorate of the Liberty Mutual Insurance Co.

O. K. Parmiter has been appointed metallurgical and sales engineer for the Firth-Sterling Steel Company, McKeesport, Pa., and G. J. Comstock, formerly metallurgist International Silver Company, has been made director of research for the former company.

R. H. Sperring, formerly district manager of the Hevi Duty Electric Company of New York, has sent in his resignation. Up to the present time he has made no other arrangements for the future. His present address is 25 Church Street, New York City.

Martin Fleischmann has recently taken charge of the metallurgical laboratory of the Union Drawn Steel Company, Beaver Falls, Pa. His address is 3415 Sixth Avenue, Beaver Falls.

J. H. Ridge has been appointed branch manager of the Pittsburgh Branch of The Timken Roller Bearing Service and Sales Company.

Clyde H. Burgston, member A. S. S. T., has been promoted to assistant superintendent of the Union Malleable Iron Works, East Moline, Ill.

The Stanley P. Rockwell Company, of Hartford, Conn., has available the following bulletins: No. 2605 A Guide for Those Contemplating the Purchase of New Heat-Treating Equipment; No. 2607 The Mystery Taken Out of Hardening; No. 2609 Why Steel Cracks; 2610A Application of Rockwell Dilatometer to Furnaces Other Than Our Own Manufacture; 2610B A Few Typical Volcrit Hardening Curves; and No. 2611 Comparison of Methods of Precision Heat-Treatment. Any or all sent gratis upon request.